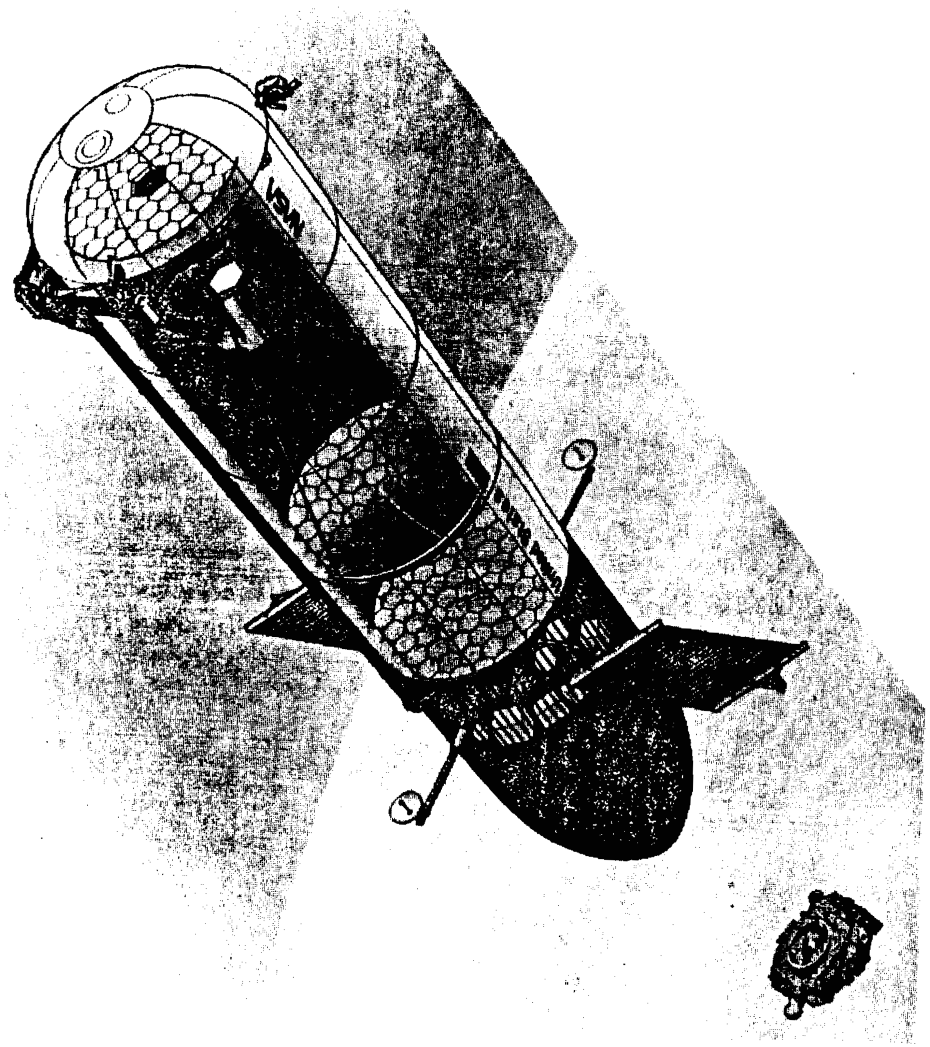
February 1988

External Tank Gamma Ray Imaging Telescope Study

Final Review
Phase II



(NASA-CR-179320) EXTERNAL TANK GAMMA RAY IMAGING TELESCOPE STUDY. FINAL REVIEW, PHASE 2 (Martin Marietta Corp.) 147 p CSCL 03A

N88-22834

Unclas
G3/89 0133310

MARTIN MARIETTA
MANNED SPACE SYSTEMS

The White House

Office of the Press Secretary

For Immediate Release

February 11, 1988

Fact Sheet

Presidential Directive on National Space Policy

The President approved on January 5, 1988, a revised national space policy that will set the direction of U.S. efforts in space for the future. The policy is the result of a five-month interagency review which included a thorough analysis of pre- Presidential decisions, the National Commission on Space report of the Space Shuttle and expendable launch vehicle acci- of this review was to consolidate and update activities to provide a broad polic the future.

processes for eval-

posals; and

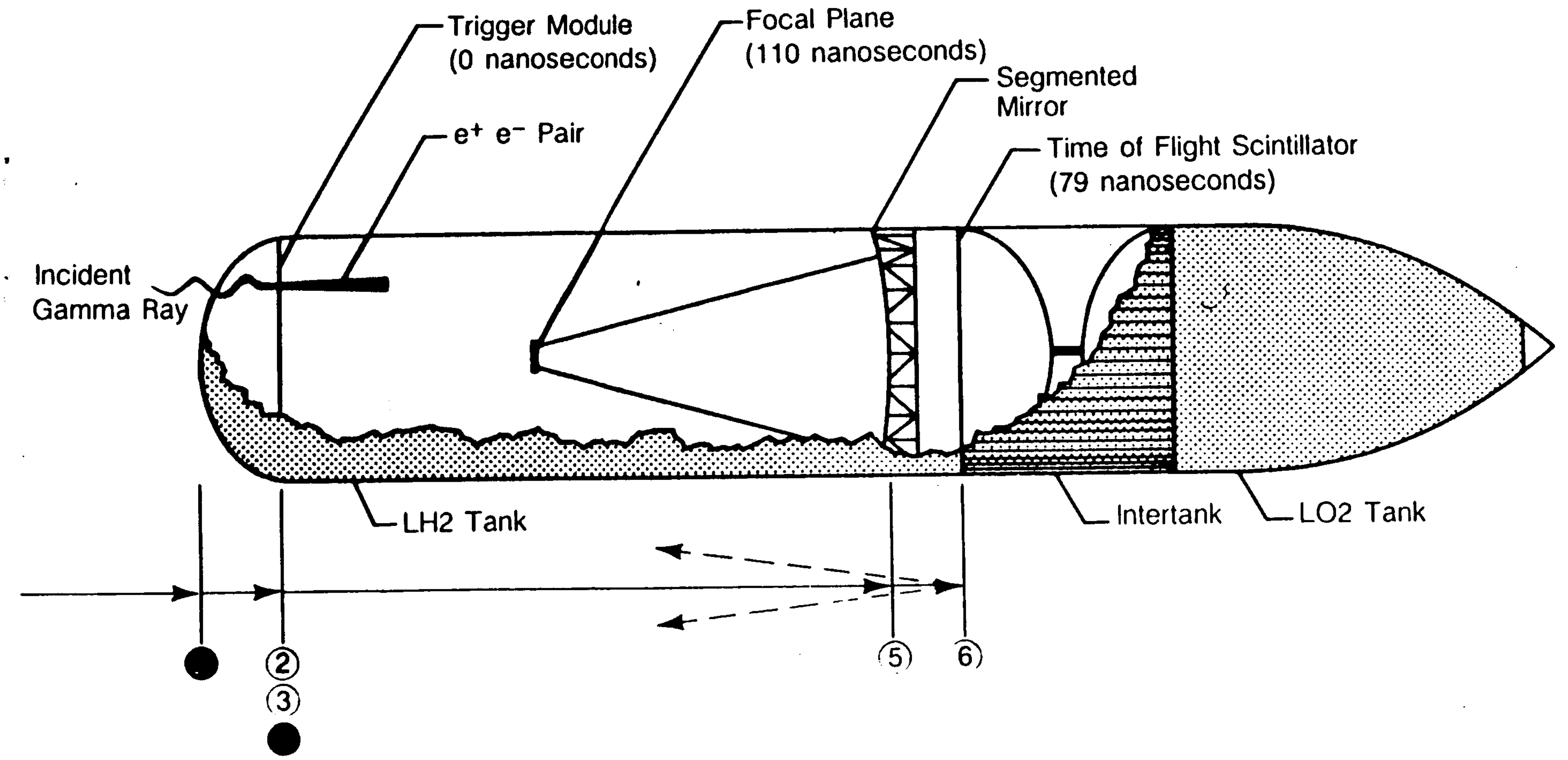
federally funded microgravity research to the commer-

rance of Executive Order 12591.

NASA will continue to be responsible for making judgments on the safety of experiments and for making manifesting decisions for manned space flight systems.

4. External Tanks: The Administration is making available for five years the expended external tanks of the Shuttle fleet at no cost to all feasible U.S. commercial and nonprofit endeavors, for uses such as research, storage, or manufacturing in space.

NASA will provide any necessary technical or other assistance to these endeavors on a direct cost basis. If private sector demand exceeds supply, NASA may auction the external tanks.



The detecting of a gamma ray

A gamma ray enters the gas-filled External Tank (ET) ● and passes through a device (scintillator) ② that detects charged particles. The gamma ray, being neutral, will not be detected at this time. The gamma ray then enters a converter ③ that changes the gamma ray into a negative-positive (electron-positron) pair. The pair immediately enters a second scintillator ● where a pulse is produced that indicates a negative-positive pair has passed through the detector. The pair emit light as they travel the length of the telescope. The light is reflected from the mirror ⑤ onto the focal plane in the form of two rings of light. Data from the reflected light rings are used to determine the energy and direction of the gamma ray. After the pair continue through the mirror, they pass through a third scintillator ⑥ that detects their arrival and provides a time of flight measurement.

This sequence of events verifies that a gamma ray has been detected by the telescope.

Agenda

Introduction	
Study Background	M. Nein
Science Background	M. Nein
Contract Overview	T. Mobley
Configurations	J. Fikes
ET-GRIT Study Results	
Telescope Attitude Control	J. Fikes
Meteoroid/Space Debris Protection	N. Elfer
Neutral Buoyancy Simulations	F. Baillif
Mission Operations Concepts Summary	S. Elrod
Thermal Control	S. Tucker
Programmatics	F. Baillif
Summary	M. Nein

Study Background

ET-GRIT Contract Support

- National Aeronautics and Space Administration
  - Marshall Space Flight Center
- Martin Marietta Corporation
  - Manned Space Systems
- Smithsonian Astrophysical Observatory
- Essex Corporation
  - Space Systems Group

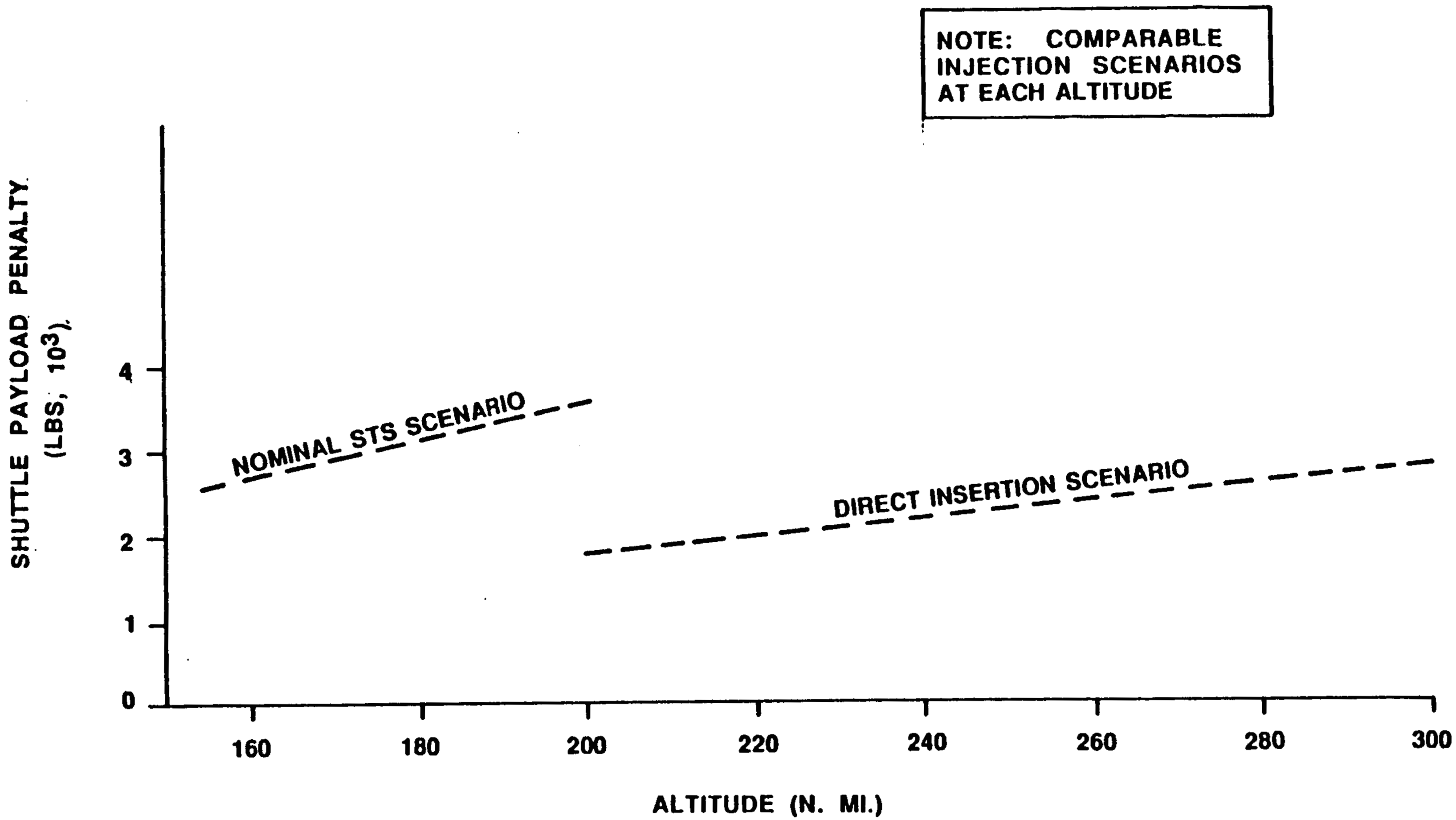
ET GRIT STUDY HISTORY

PHASE I JUNE-DEC. 86 CODE M FUNDING $ 93K	REQUIREMENTS PREL. CONFIGURATIONS IDENTIFY TECHNOLOGY ISSUES ET MODIFICATION IMPACTS COST AND SCHEDULES	MSFC MMC SAO
PHASE II JAN. 87-88 FUNDING $103K +*	EVALUATE KEY TECHNICAL ISSUES – THERMAL CONTROL – OPERATIONS (NBS) – ATTITUDE CONTROL SUPPORT ET UTILIZATION SYMPOSIUM	MSFC MMC SAO ESSEX

* SUPPORTED BY MMC IRAD

EXTERNAL TANK UTILIZATION

SHUTTLE PAYLOAD PENALTY VS ALTITUDE FOR CARRYING ET TO CIRCULAR ORBIT



1-613-8-2T

ET GRIT STUDY CONCLUSIONS
PHASE I

- METEOROID/SPACE DEBRIS PROTECTION REQUIRED
  - PENETRATIONS → LOSS OF EXPERIMENT
  - IMPACTS → SECONDARY DEBRIS GENERATION
- ON-ORBIT INGRESS AND ASSEMBLY
  - DEMONSTRATED FEASIBILITY OF INGRESS THROUGH NEUTRAL BUOYANCY SIMULATIONS
  - DEVELOPED CONCEPT FOR ASSEMBLY AND IDENTIFIED NEED FOR DEMONSTRATION
- THERMAL CONTROL
  - ANALYZED THERMAL CONDITIONS, IDENTIFIED GRADIENTS IN GAS VOLUME,
  - IDENTIFIED NEED FOR ADDITIONAL ANALYSES AND FOR SIMULATIONS
- ORBITAL LIFE TIME
  - DEPLOYMENT ALTITUDE
- ATTITUDE CONTROL
  - CMGS/MAGNETIC TORQUERS/MOMENTUM MANAGEMENT
- TANK PRESSURANT
  - H_2 PREFERRED FOR INSTRUMENT OPERATIONS
  - CO_2 SELECTED FOR SYSTEMS OPTIMIZATION (LOWER LEAKAGE RATE, COMPACT STORAGE)
- PRELIMINARY CONFIGURATION
  - UTILIZATION OF INTERTANK FOR SUBSYSTEM INSTALLATION
  - OMV DOCKING INTERFACE
  - "OFF THE SHELF" SPACECRAFT SUBSYSTEMS
- MANUFACTURING "UNIQUE ET" WILL NOT IMPACT DELIVERY SCHEDULES OF STS PROGRAM
- ET-GRIT COULD BE OPERATIONAL WITHIN 5-6 YEARS FROM ATP
- LIFE CYCLE COST OF THE PROGRAM ~ $190M

ET-GRIT CONTRACT PHASE II STUDY OVERVIEW

TASKS

- INSTRUMENTATION REQUIREMENTS
- DATA MANAGEMENT REQUIREMENTS
- SCIENTIFIC APPLICATIONS
- TELESCOPE ATTITUDE CONTROL TIMELING
- THERMAL CONTROL
- INTERTANK LOADS/STRESS ANALYSIS
- EVA ENHANCEMENT
- SCIENCE INSTRUMENTS INSTALLATION
- LH_2 TANK SIMULATOR DESIGN
- NBS TEST PLAN/SUPPORT
- NBS SIMULATOR INSTALLATION & TOOLS
- SUPPORT ET UTILIZATION SYMPOSIUM

Science Background

Evolution Of Gamma-Ray Astronomy (100 MeV < E < 10 GeV)

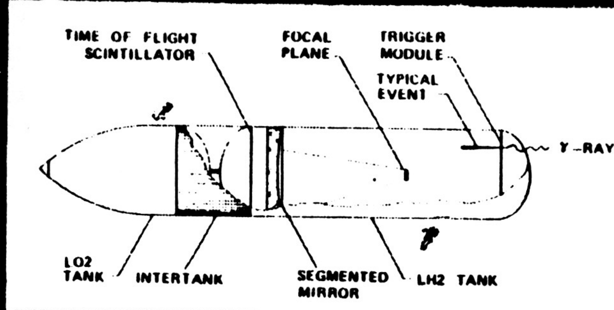
Device	Launch	Duration	Area	Purpose
Balloon Experiment	* 1960's	Tens Of Hours	< 1000 cm^2	Pioneering
OSO - 3	Mar 1967	16 Months	46 cm^2	Background
SAS - 2 *	Nov 1972	7 Months	640 cm^2	Survey
Cos-B *	Aug 1975	81 Months	576 cm^2	Galactic Survey
GRO *	1990 ?	2 - 4 Years	6,500 cm^2	All Sky Survey
GRIT	Mid - 1990s	5 years	250,000 cm^2	Pointed Studies

* Spark Chamber With Large Field Of View

ET - GAMMA RAY IMAGING TELESCOPE
(ET - GRIT)

UTILIZE EXTERNAL TANK AS LARGE γ-RAY OBSERVATORY

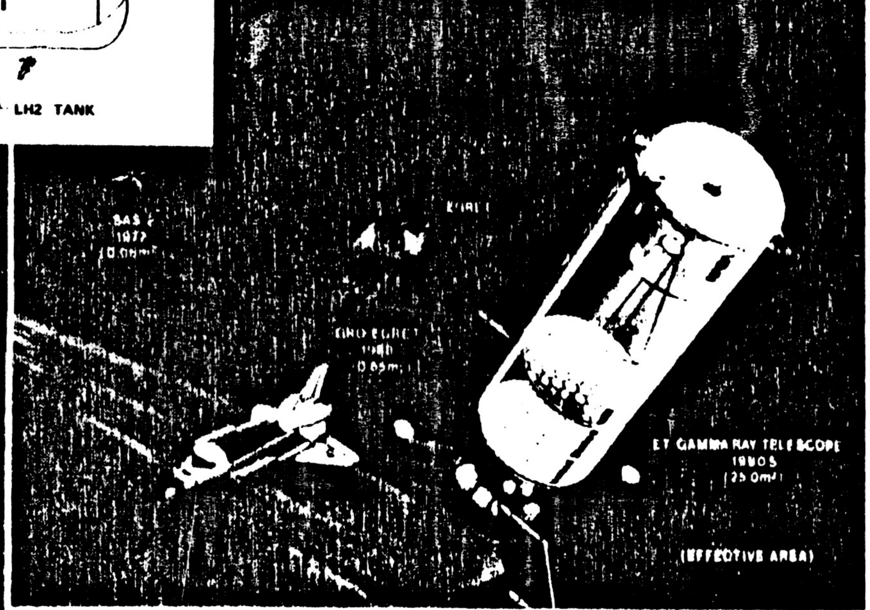
- GAS - CHERENKOV TELESCOPE
  - AREA 40 X GRO (250,000 cm^2)
  - 5° FIELD OF VIEW
  - ENERGY THRESHOLD 85 MeV (125 MeV EFFECTIVE)
  - TIME RESOLUTION ~5 NANO SECONDS
  - EFFECTIVE LIFETIME ~5 YEARS



OBSERVE WIDE-RANGE OF ASTROPHYSICAL SOURCES

- γ-RAYS PRODUCED IN VIOLENT PROCESSES
- POINTED OBSERVATIONS OF DISCRETE SOURCES
  - COMPACT OBJECTS: NEUTRON STARS, PULSARS, BLACK HOLES
  - EXTRA GALACTIC: QUASARS, AGN, BL-LAC
- DIFFUSE GALACTIC EMISSION
- IDENTIFY "MYSTERY" SOURCES
- MAP NEARBY GALAXIES
- SEARCH FOR BURSTERS/OTHER VARIABILITY
- EXTEND GRO OBSERVATIONS
- POTENTIAL FOR DISCOVERIES

COMPARISON OF GAMMA-RAY TELESCOPES



MSFC - 2 87-ST 2894-8A

Detection Technique

- Convert gamma ray into an electron-positron pair
- Detect the conversion with an adjacent plastic scintillator
- Relativistic charged pair generates visible light in gas
- Image and detect two cones of light using conventional optics
- Additional scintillator behind mirror detects exiting pair
- Charged particle veto scintillator in front of converter
- Event trigger based on high speed three-fold time-delayed coincidence

Virtues Of Using External Tank

- Detection Technique Requires Large, Clean, Rigid, Light-Tight, Gas-Tight, Thin-Walled Pressure Vessel
- 65,000 Lb "Spacecraft" Currently Is Taken To 98% Of Orbital Velocity
- Unconventional Approach For Deployment Of A Large Telescope Within Conventional Capability
- Integral Strengthing Of Telescope For Launch As An Assembled Unit Would Be Prohibitive

Contract Overview

ET-GRIT Contract Overview

- **Contract No:** NAS8-3694

- **Duration:** May, 1986 - February, 1988

- **Funding:**
  1986 ~ $93K
  1987 ~ $88K
  6.8K Symposium for ET Uses
  8.2K EVA Tool and NBS Diving Support
  $103K

- **Purpose:** Further Develop the External Tank Gamma Ray Telescope Concept

  Address Certain Key Technology and Programmatic Issues

  Develop a Catalogue of Potential Scientific Experiments Applications for an ET Onorbit

  Planning and Support of an ET-GRIT NBS Test

ET-GRIT Phase I Study Tasks

- Preliminary Requirements Defined
- Identified Technical Issues
- Preliminary Configuration
- Manufacturing "Unique ET" Will Not Impact Delivery Schedules Of STS Program
- ET-GRIT Could Be Operational Within 6 Years From ATP
- Life Cycle Cost Of The Program ~ $190M (1986 $)

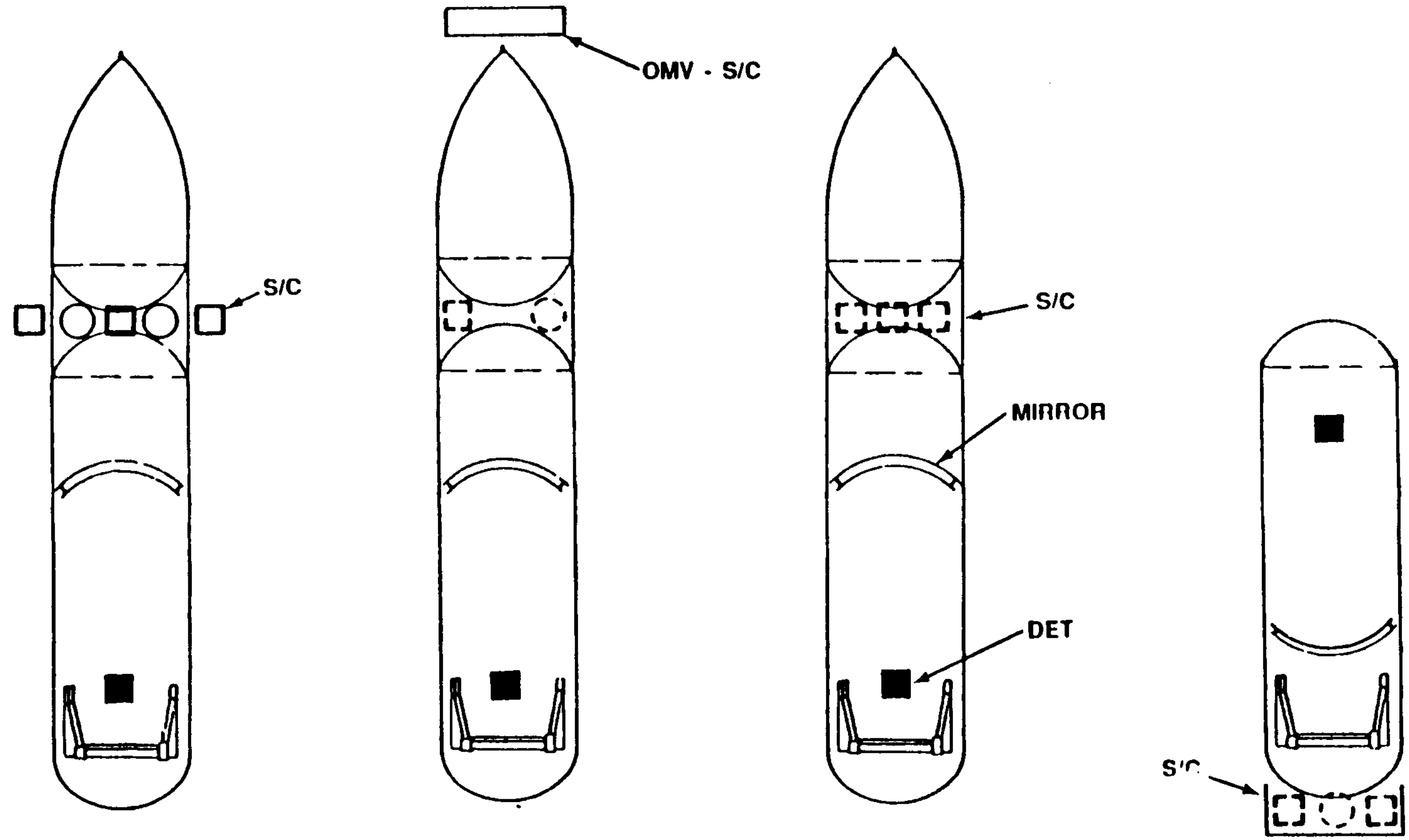
ET-GRIT Phase II Study Tasks

Task		Results
1.1	Instrumentation Requirements	Supported MSFC Effort
1.2	Data Management Requirements	Supported MSFC Effort
1.3	Scientific Applications	Final Report Published of Symposium Results
2.1	Telescope Attitude Control Timeline	Supported MSFC Effort
3.1	Thermal Control	Orbital Heating Analysis Performed
3.2	Intertank Loads/Stress Analysis	Preliminary Analysis Completed
3.3	EVA Enhancement	Concepts Identified For • TPS Removal • Handholds • LH2 Tank Entry • Foot Restraints • Siphon Removal • Attachment Hardware
3.4	Science Instruments Installation	Completed
3.5.1	NBS Test Plan/Support	Completed
3.5.2	LH2 Tank Simulator Design	Completed Simulator Design
3.5.3	Hardware Buoyancy Analysis	Completed LH2 Siphon Assembly Neutral Buoyancy Analysis and Design
3.5.4	NBS Simulator Installation & Tools	Completed Installation & Fabricated Two EVA Tools
3.6	Micrometeroid/Space Debris Protection System Concept	Developed Concept for a System

Configurations

1-5018-7

ET-GRIT CONFIGURATION OPTIONS



① MSFC BASELINE
- EXT' SUBSYSTEMS
- AFT LOS

② OMV OPTION
- OMV SPACECRAFT
- I-T TEL' GAS

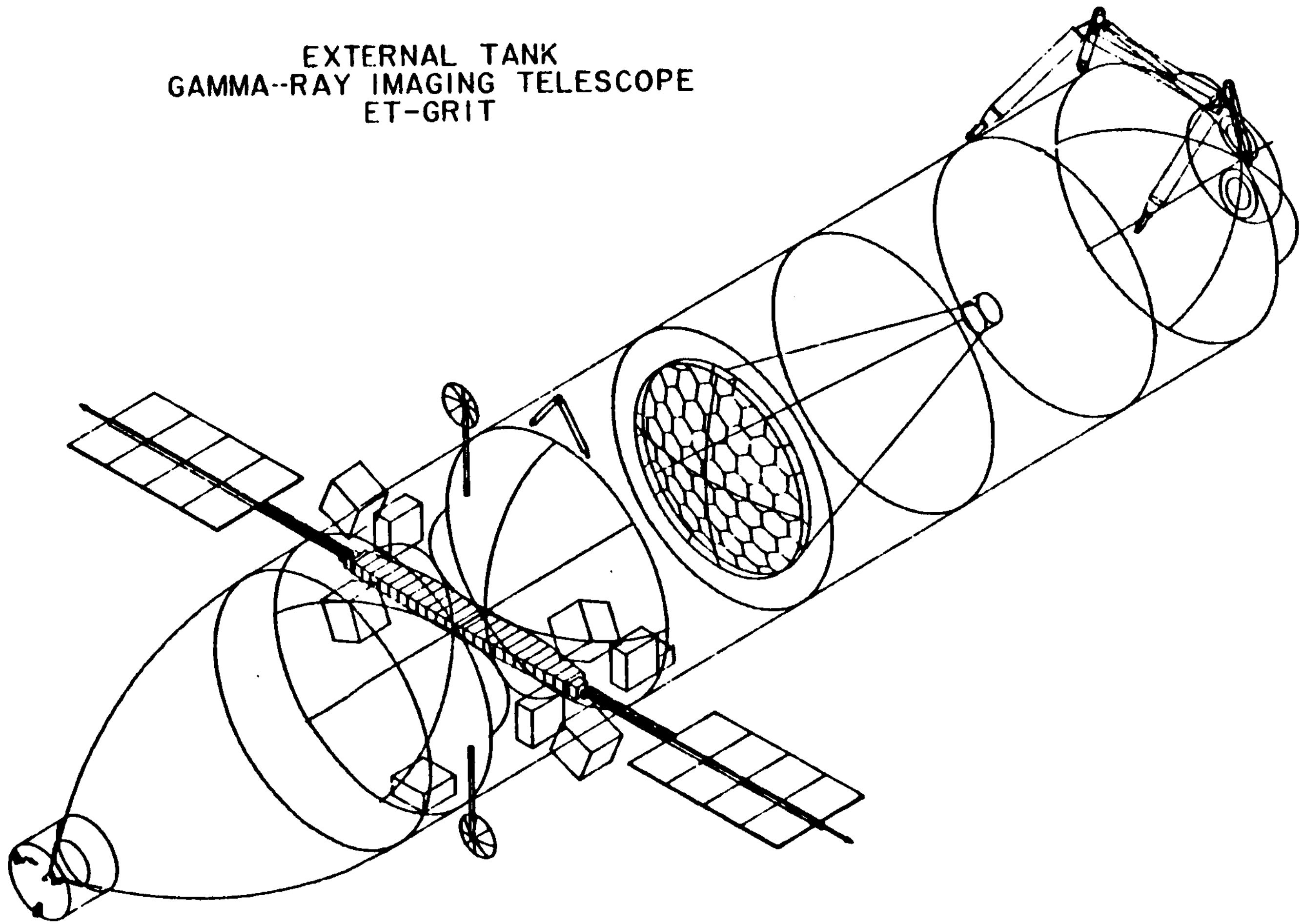
③ MMC BASELINE
- INT' SUBSYSTEMS
- AFT LOS

④ LHT OPTION
- USE ONLY H_2 TANK
- INVERTED MIRROR
- AFT CARGO S/C

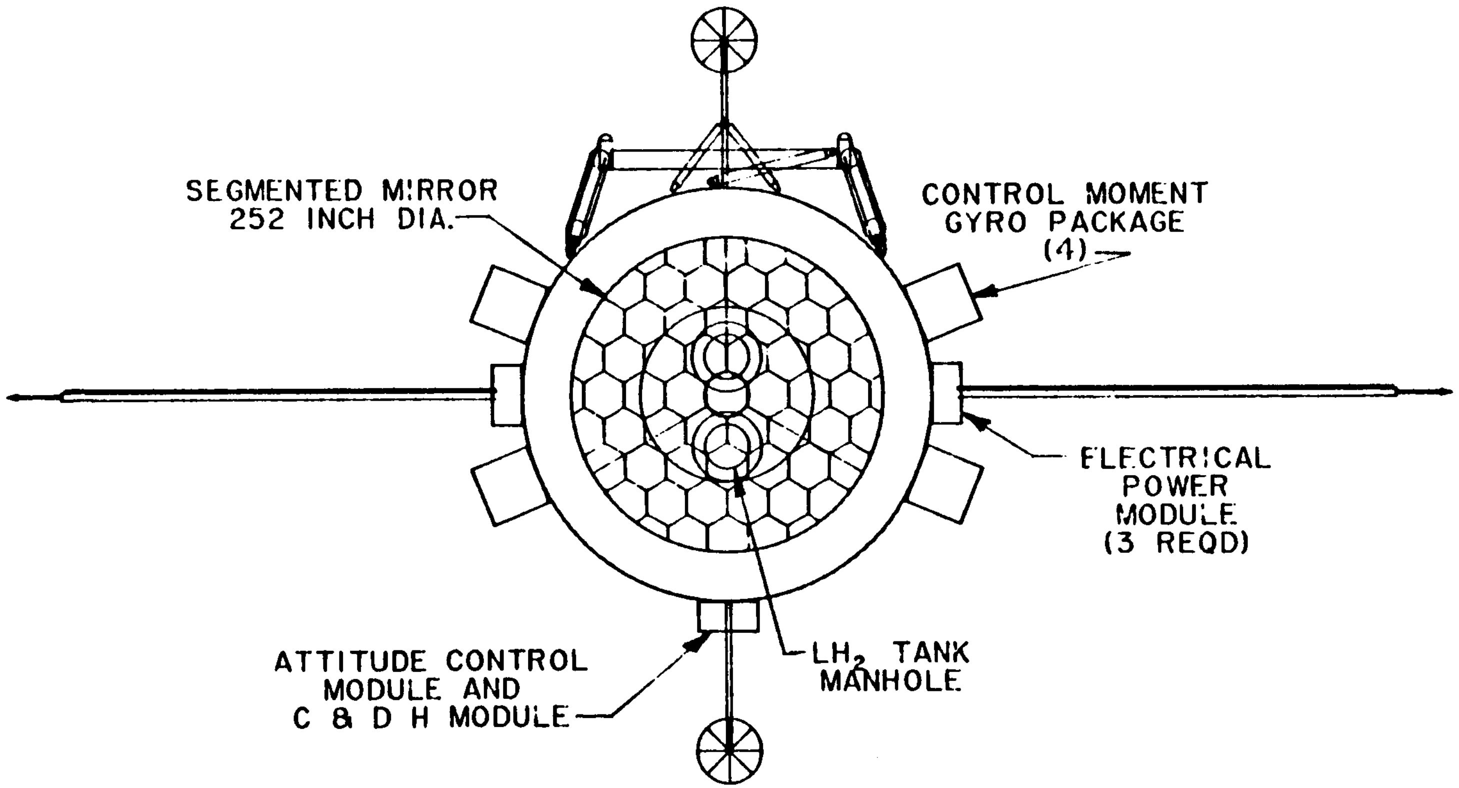
(SOLAR ARRAYS NOT DEPICTED)

PD12/MSFC

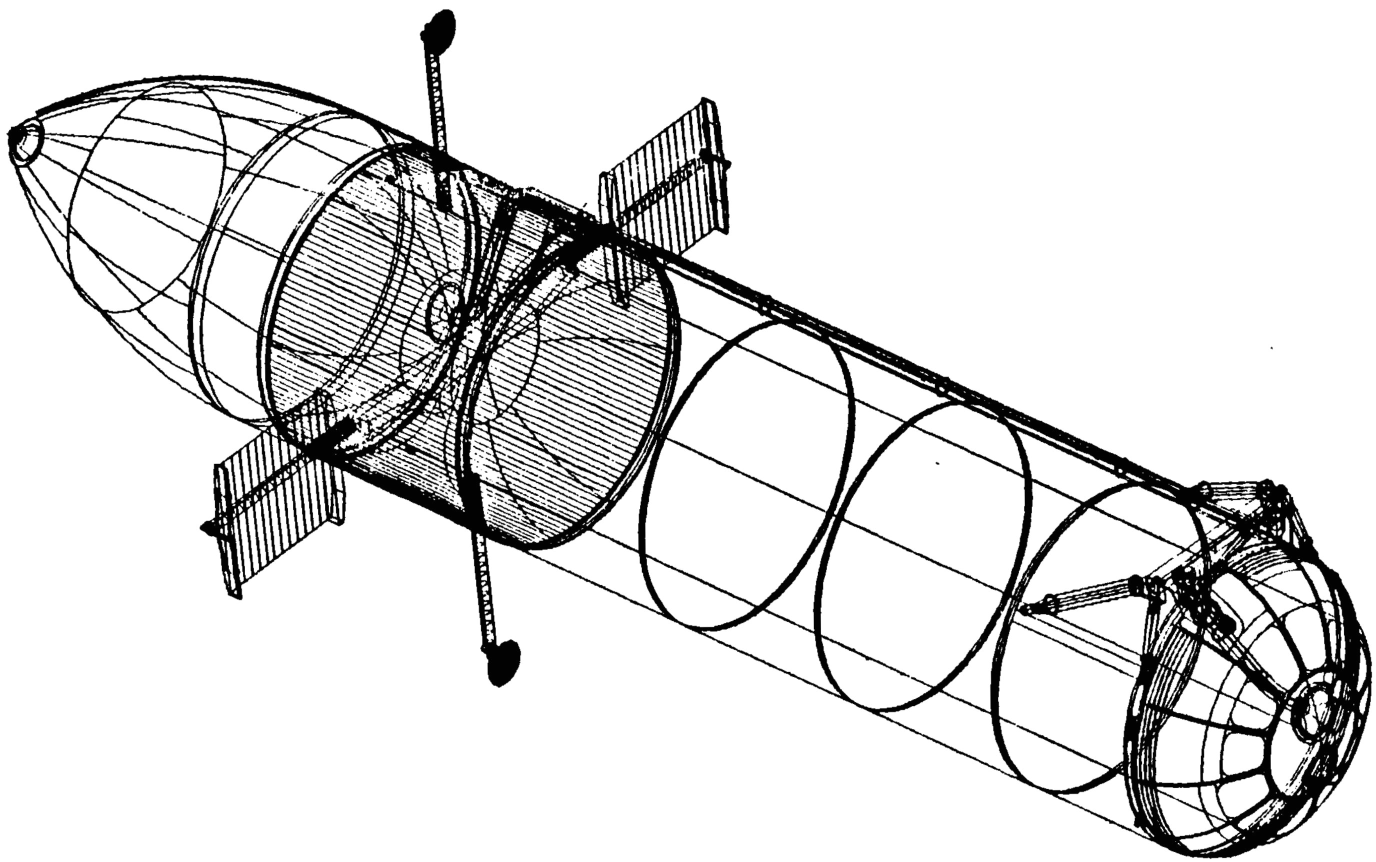
EXTERNAL TANK
GAMMA-RAY IMAGING TELESCOPE
ET-GRIT



EXTERNAL TANK
GAMMA-RAY IMAGING TELESCOPE
ET-GRIT
VIEW LOOKING FORWARD

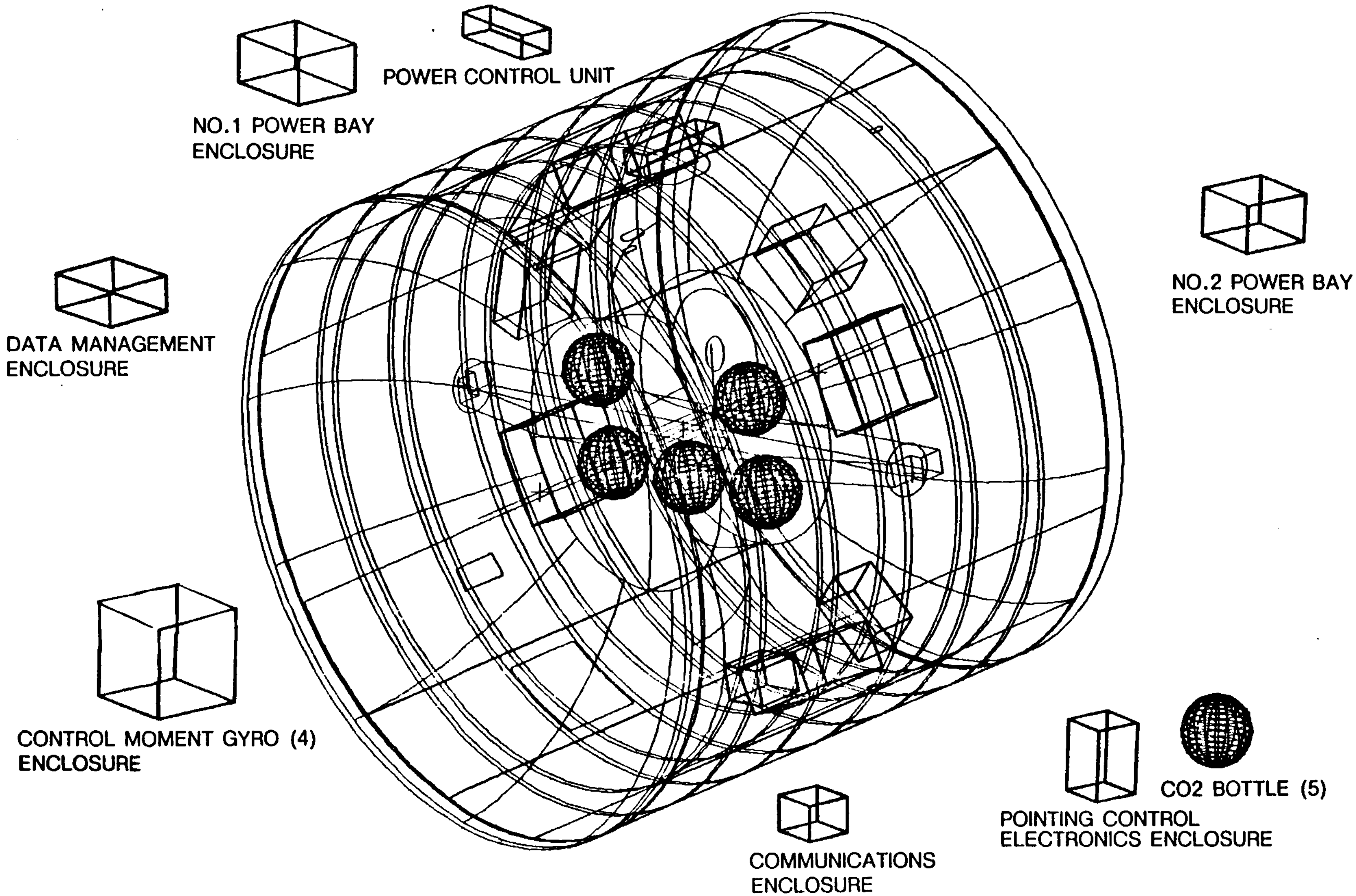


External Tank Onorbit



MARTIN MARIETTA
MICHOUD AEROSPACE

Spacecraft Hardware Installations - Intertank



MARTIN MARIETTA
MICHOUD AEROSPACE

ET-GRIT Contract
1987 Study Results

MARTIN MARIETTA
MANNED SPACE SYSTEMS

Scientific Components Requirements

ET-GRIT Scientific Components

	Quantity	Weight
Scintillators		
Time of Flight Modules	85	743
Time of Flight Support	1	306
Trigger Modules	54	2856
Trigger Module Support	1	477
Mirror	1	1229
Mirror Alignment Assembly	1	717
Focal Plane Assembly	1	254
Focal Plane Support	1	219
Alignment Transfer Assemblies	3	TBD
Star Trackers	3	75
Cable Harnesses/ Science Electronics Assemblies	TBD	~292

CO2 Effects on Polyvinyltoulene Scintillator

- CO2 Tends to Adsorb - Hazing
- CO2 Causes No Breakdown of Composition

Radiation Effects on Polyvinyltoulene Scintillator

- Will Withstand 10^{10} Gamma Radiation Dose Up To 30 Years

Intertank Stress Analysis

MARTIN MARIETTA
MANNED SPACE SYSTEMS

Intertank Subsystem Components

	Pounds
• No. 1 Power Bay	**753**
- Power Distribution Boxes	
- Batteries (Nickel Cadmium)	
- Charge Current Controllers	
- DC/DC Converters	
• No. 2 Power Bay	**520**
- Power Distribution Boxes	
- Batteries (Nickel Cadmium)	
- Charge Current Controllers	
- DC/DC Converters	
• Power Control Unit	**120**
• Communications	**68**
- SA Transmitters	
- MA Transponders	
- Diplexers	
- Circulator Switch	
- RF Transfer Switches	
- RF Multiplexers	
- Instrument Control Unit	

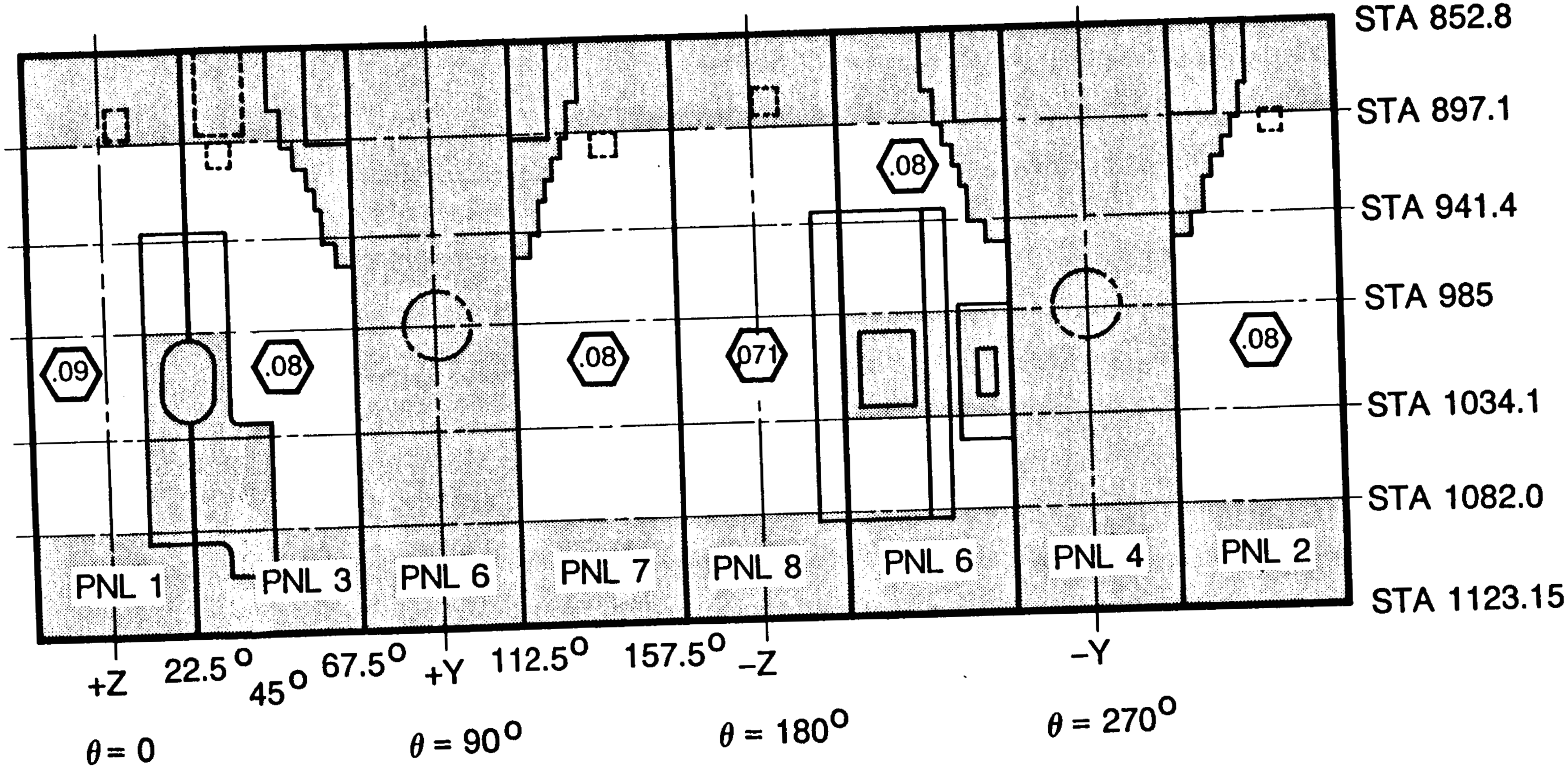
Intertank Subsystem Components, cont.

	Pounds
• **Data Management** - Computer - Data Interface and Management Unit - Tape Recorders - Crystal Oscillators	357
• **Pointing Control Electronics**	130
• **Control Moment Gyros**	357
• **CO2 Pressure Vessels - Loaded**	2499
• **Support Structures**	1000

Intertank Areas to Avoid Mounting Equipment

- Forward and Aft End Bays
  - Station 852.8 - 897.1 (All Angular Locations)
  - Station 1082 - 1123.15 (All Angular Locations)
- Thrust Panels at $\theta = 67.5° - 112.5°$ and $\theta = 247.5° - 292.5°$
- Access Door and Umbilical Plate Location $\theta = 202.5° - 247.5°$ Station 941.4 - 1082
- LO2 Feedline Location $\theta = 13.75° - 36.25°$ Between Station 985 - 1082
- Thrust Doubler Areas $\theta = 45° - 67.5°$, $\theta = 112.5° - 135°$, $\theta = 225° - 247.5°$ and $\theta = 292.5° - 315°$ Between Stations 852.8 - 941

Intertank Mounting Locations



NOTE: SHADED AREAS INDICATE NO EQUIPMENT MOUNTING.

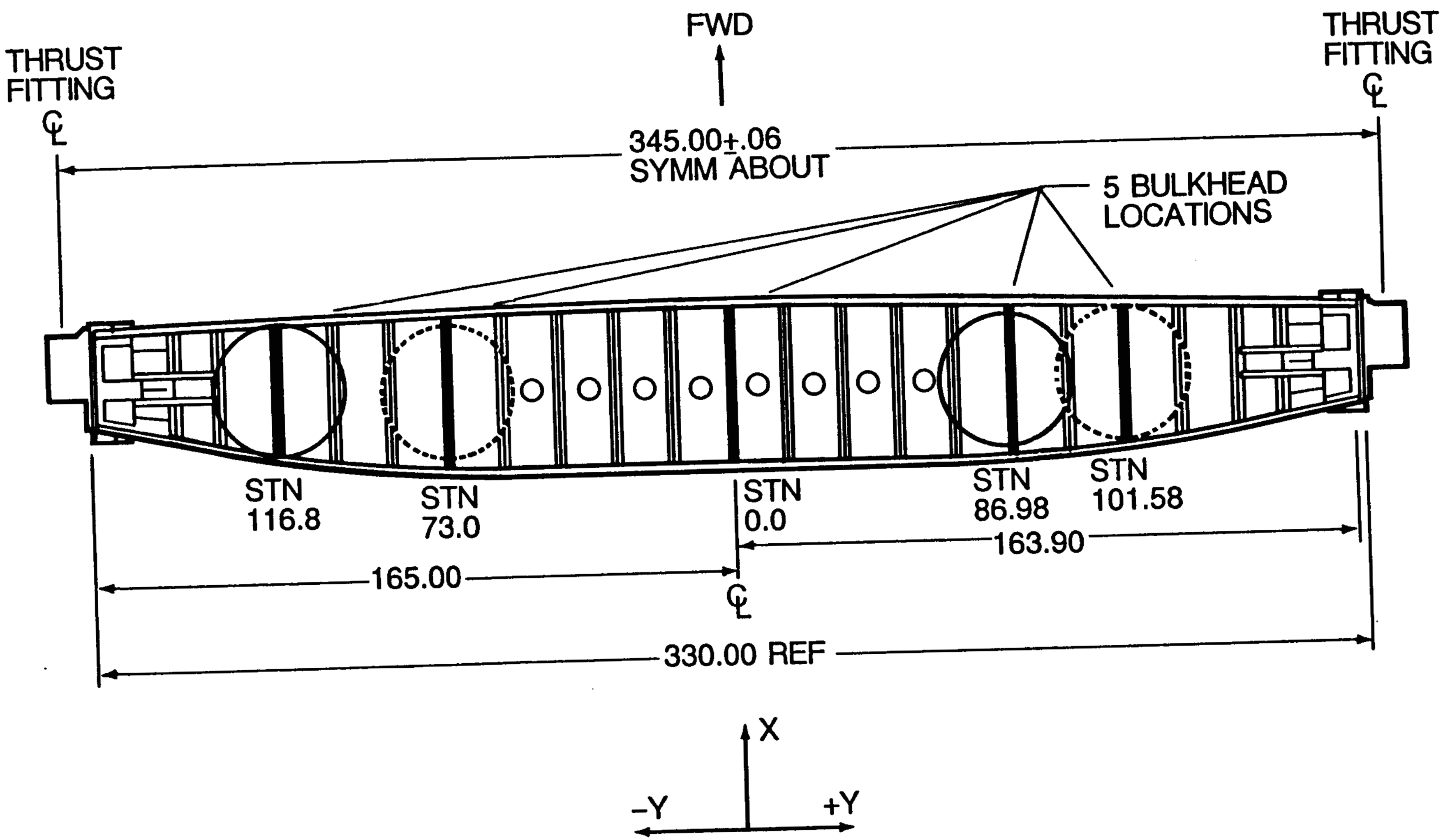
FWD

MARTIN MARIETTA
MANNED SPACE SYSTEMS

CO2 Pressure Vessels Placement

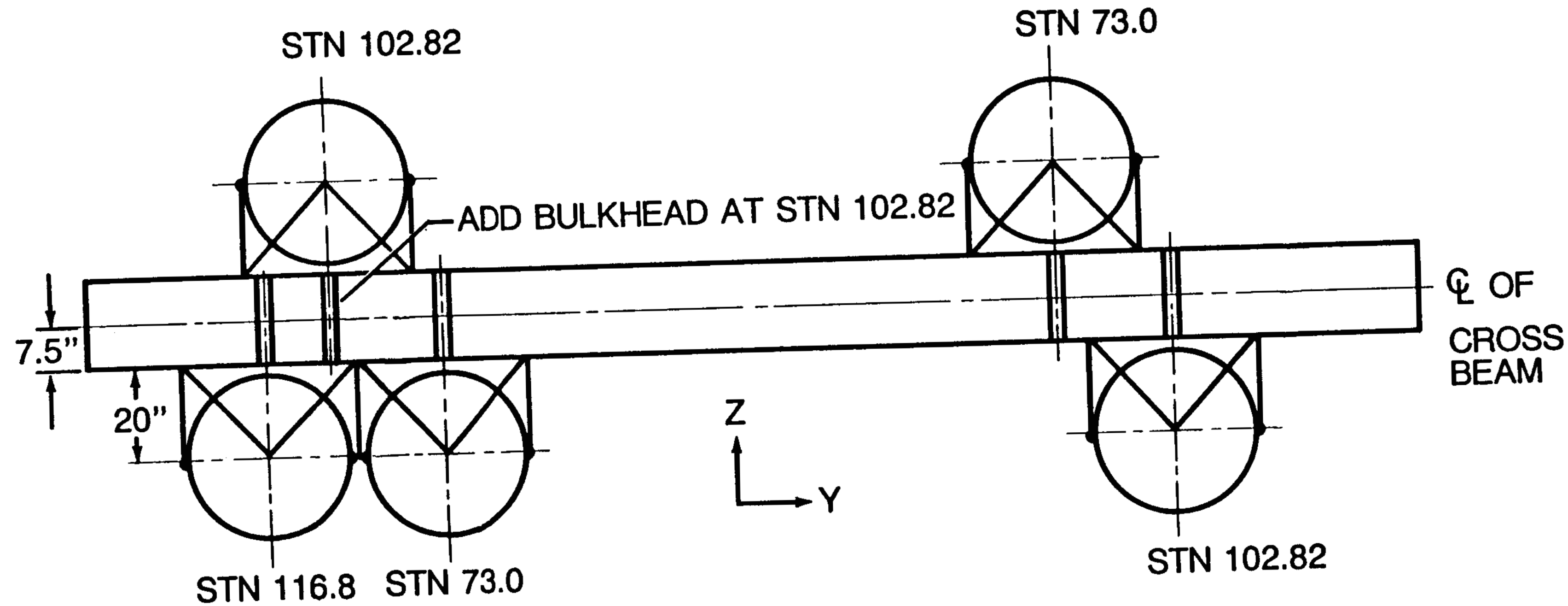
- **CO2 Pressure Vessels**
  - **Mount on Side Faces of the Intertank Crossbeam**
    - Place on Outboard Location to Reduce Crossbeam Deflections
  - **Increase Web Thickness from Station 73.0 to the End of Crossbeam**
  - **Add Bulkhead at Station 102.82 for Reenforcement**

CO_2 Pressure Vessels on Intertank Crossbeam



MARTIN MARIETTA
MANNED SPACE SYSTEMS

CO2 Pressure Vessels – Top View



Telescope Attitude Control

ET-GRIT ATTITUDE CONTROL REQUIREMENTS

- ORIENTATION REQUIREMENTS
  - CELESTIAL POINTING: MOST KNOWN SOURCES ARE IN THE GALACTIC PLANE
  - MUST HAVE UNIFORM GALACTIC PLANE COVERAGE OVER 1 YEAR
  - NO SUN OR MOON AVOIDANCE CONSTRAINTS: MAY USE AS AN OCCULTING DISK FOR SPECIFIC TYPES SCIENCE
  - MUST RECEIVE SOLAR POWER WHILE IN THE SUN LIGHT

- ACCURACY REQUIREMENTS
  - POINT WITHIN A 1 DEG DEADBAND ($\pm$ 0.5 DEG)
  - STABILITY NOT SPECIFIED (SLOW DRIFT PERMITED)
  - ROLL CONTROL NOT SPECIFIED (SLOW ROLL PERMITED)
  - DURATION OF 30 MIN MINIMUM TO DAYS PER TARGET
  - 1 ARC MIN ATTITUDE DETERMINATION
  - SLEW RATE TO MINIMIZE DOWNTIME ($\sim$ 0.1 DEG/SEC)

ET-GRIT Attitude Control System Equipment List

Item	No Used	Unit Wt (lb)	Power (W)	Total Wt (lb)	Power (W)
				5425	549
Interface Elect	1	100	67	100	67
Magnetometer	2	2	1	4	2
Fine Sun Sensor	1	3	2	3	2
Star Trackers	3	25	18	75	54
Rate Gyro	1	37	22	37	22
Coarse Sun Sensor	2	4	1	8	2
Y-Z Magnetic Coils	2	587	25	2348	100
X Magnetic Coil	2				
DG-CMG	4	650	75	2600	300
Interface Structure	-	250	0	250	0

Estimated Packaging Volume

Sensors + Electronics, 4' x 4' x 2' Box

DG-CMG, 4' x 4' x 4' Box - Each Unit

1-5046-7-9T

ESTIMATE OF ET-GRIT MASS PROPERTIES

MASS (LB)

TELESCOPE (ET)	66,939
METEOROID SHIELD	3,360
SUBSYSTEMS (AT ET CG)	15,000
	85,299 LB

INERTIA (SLUG - FT^2)

IXX = 540,722

IYY = 4,718,012

IZZ = 4,715,012

MAX Δ I = 4,177,290 SL - FT^2

OBSERVATIONS

- ET-GRIT HAS A VERY UNFAVORABLE MASS DISTRIBUTION
- THREE TIMES THE MASS OF HST, BUT ABOUT 83 TIMES MORE DIFFICULT TO HOLD AGAINST GRAVITY FORCES.

1-5169-7-10T

ET-GRIT CONTROL NEEDS

PARAMETER ESTIMATES

- ORBIT ALTITUDE 250 NMI, RATE 1.114E-3 RAD/SEC
- INERATIA DELTA 4,177,290 SL-FT^2
- AVERAGE MAGNETIC FIELD 0.3 GAUSS

PEAK GRAVITY

- TORQUE = 7.8 FT-LB
- CYCLIC, HQ = 6,980 FT-LB-S
- SECULAR, HS = 21,929 FT-LB-S/ORBIT

CONTROL NEEDS (ALL SKY POINTING)

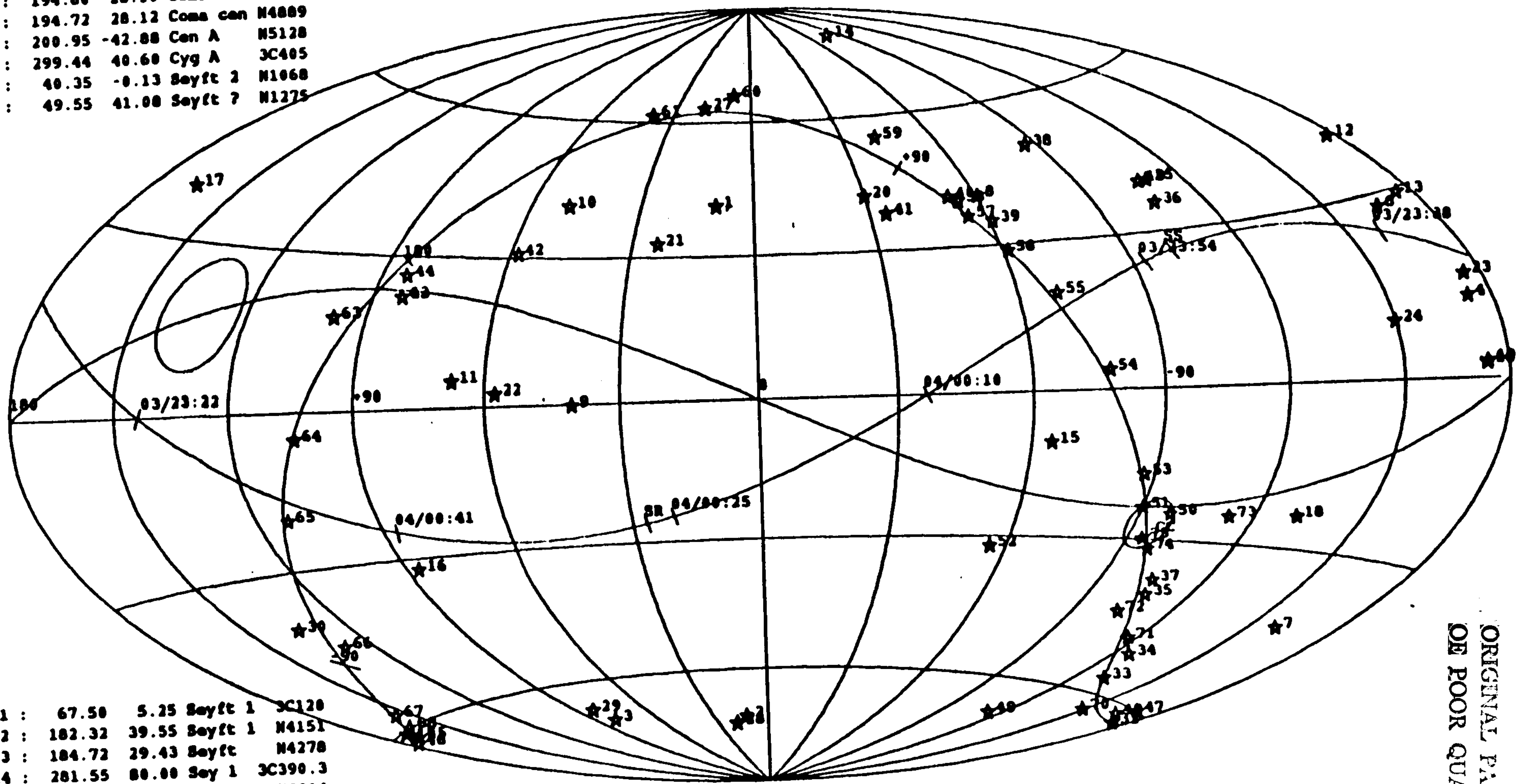
- FOUR SPERRY 4500 DG-CMGS
  - 18,000 FT-LB-S MOMENTUM AT SATURATION
  - UP TO 800 FT-LB TORQUE PER AXIS

- MOMENTUM MANAGEMENT
  - ATTITUDE MANEUVERING
    (AND/OR)
  - HYDRAZINE = 0.62 LB/ORBIT = 3,395 LB/YEAR
    (OR)
  - MAGNETIC TORQUES AT 176,967 A-M^2/AXIS (10,300 LB)

- ALL PROPULSION OPTION
  1.52 LB/ORBIT (AVERAGE) = 8,295 LB/YEAR

Plot generated on Tue Dec 30 14:33:44 1980
Launch 1990 JUL 29 at 21:00:00 GMT
Objects from file:plobj.55
E.G. Xray & Gamma ray
Rev # 62 begins at03/23:22 MET
EQUATORIAL COORDINATES

	Long	Lat		
1 :	10.00	41.00	M31	N224
2 :	12.00	-72.00	SMC	
3 :	80.75	-69.40	LMC	
4 :	187.07	12.67	M87	N4486
5 :	194.60	28.10	Coma con	N4874
6 :	194.72	28.12	Coma con	N4889
7 :	200.95	-42.88	Cen A	N5128
8 :	299.44	40.60	Cyg A	3C405
9 :	40.35	-0.13	Seyft 2	N1068
10 :	49.55	41.00	Seyft ?	N1275



11 :	67.50	5.25	Seyft 1	3C120
12 :	182.32	39.55	Seyft 1	N4151
13 :	184.72	29.43	Seyft	N4278
14 :	281.55	80.00	Sey 1	3C390.3
15 :	295.32	-10.35	Seyft 1	N6814
16 :	87.00	-32.20	BL Lac:	
17 :	165.25	38.40	BL Lac:	Mk421
18 :	228.50	-24.10	BL Lac:	AP Lib
19 :	253.00	39.80	BL Lac:	Mk501
20 :	330.00	42.00	BL Lac:	BL Lac
21 :	23.70	32.88	QSO	3C48
22 :	57.75	2.60	QSO	
23 :	185.00	16.00	QSO	
24 :	210.25	9.80	QSO	
25 :	260.32	39.90	QSO	3C345

ORIGINAL PAGE IS
OF POOR QUALITY

OPTIONS FOR MOMENTUM MANAGEMENT

0 MAGNETIC TORQUERS

- OPEN CORE COILS
- ELECTROMAGNETS

0 PROPULSION

- HYDRAZINE
- BIPROPELLANT

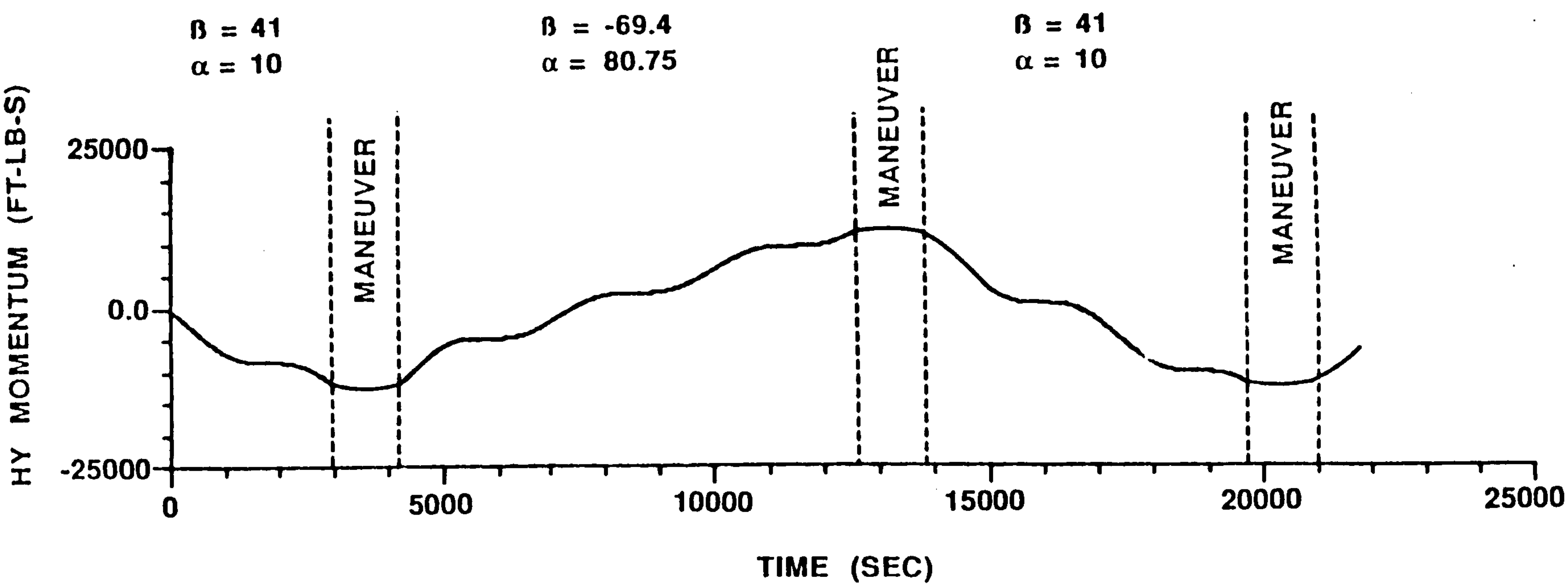
0 GRAVITY GRADIENT

- RESTRICTED POINTING
- $\boxed{\text{BROKEN POINTING}}$

1-5986-7

ET-GRIT SECULAR MOMENTUM MANAGEMENT

TARGET LOCATION ß AND α (DEG)

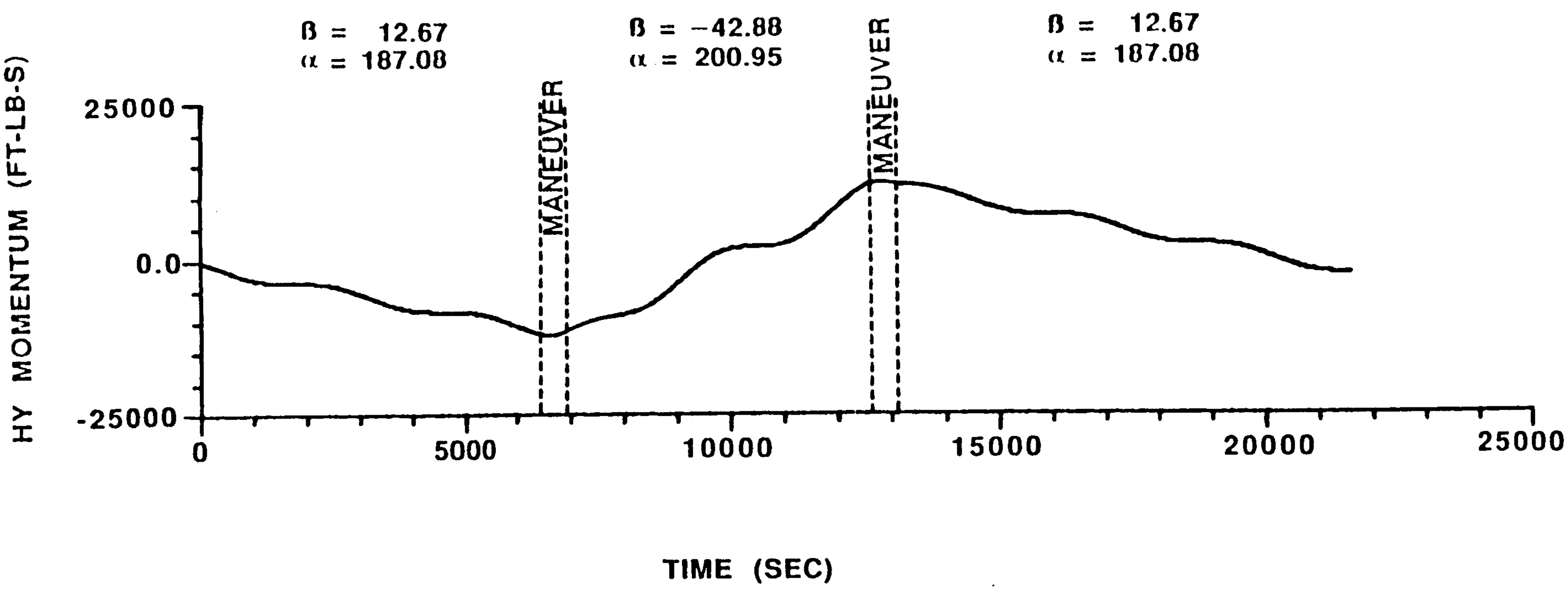


FIKES/PD12

1-5984-7

ET-GRIT MOMENTUM MANAGEMENT

TARGET LOCATION β AND α (DEG)

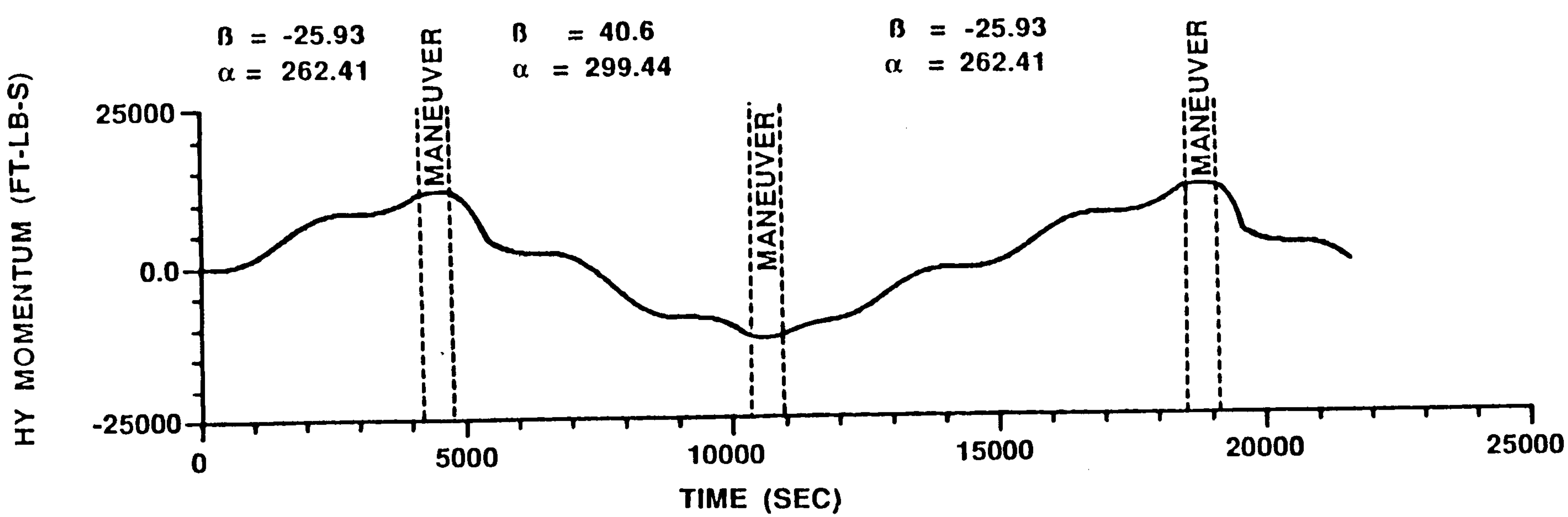


FIKES/PD12

1-5985-7

ET-GRIT SECULAR MOMENTUM MANAGEMENT

TARGET LOCATION ß AND α (DEG)



FIKES/PD12

ET-GRIT VIEWING PARAMETERS

FILENAME: FIKESAGEP
CASENAME: CASE4

PAGE: 1

REV NO.	= 2.0000	RASUN	= 159.8225	DECSUN	= 8.5055	UUEN	= 288.8929	UUEX	= 63.9323	RAM	= 220.1000
MET	= 0:01:34:17	UOM	= 366.4243	BETA	= 7.7437	METUEN	= 0:02:50:05	METUEX	= 0:01:51:06	DECM	= -16.0406
OEA	= 5.0000	RANOS	= 339.2466	IOS	= 28.5000	N	= 3.8178	SUNAA	= 5.0000	LUNAA	= 5.0000
MESA	= 72.9080										

TARGET	RASTAR (DEG)	DECSTAR (DEG)	UACQ (DEG)	ULOSS (DEG)	METACQ (D:H:M:S)	METLOSS (D:H:M:S)	BETAS (DEG)	UOMS (DEG)	OEAMAX (DEG)	OT (MIN)	OTIDARK (MIN)	SSA (DEG)	MSA (DEG)
M31	10.00	41.00	-39.40	129.72	0:01:23:58	0:02:08:16	23.10	45.16	66.90	44.30	0.00	123.24	130.02
LMC	80.75	-69.40	187.00	300.93	0:02:23:16	0:02:53:07	-80.80	243.97	9.20	29.84	0.00	94.16	91.69
M87	187.08	12.67	114.40	283.43	0:02:04:15	0:02:48:32	24.21	198.92	65.79	44.28	0.00	27.10	50.59
CENA	200.95	-42.88	149.38	318.63	0:02:13:25	0:02:57:45	-21.43	234.00	68.57	44.33	0.00	63.56	36.06
GX1+4	262.41	-25.93	196.83	366.82	0:02:25:51	0:03:10:22	1.92	281.82	88.08	44.53	0.00	104.98	32.44
CYGA	299.44	40.60	267.12	430.26	0:02:44:15	0:03:26:59	53.50	348.69	36.50	42.73	0.00	118.41	86.17
3C48	23.70	32.88	-32.59	137.21	0:01:25:45	0:02:10:14	11.33	52.31	78.67	44.48	0.00	121.23	151.46
3C273	186.64	2.33	118.61	288.27	0:02:05:21	0:02:49:48	14.78	203.44	75.22	44.44	0.00	27.39	45.89
NGC4151	182.33	39.55	93.97	259.87	0:01:58:54	0:02:42:21	44.74	176.92	45.26	43.46	0.00	37.00	70.69

BETA - Angle between the solar vector and its projection onto the orbit plane

BETAS - Angle between a vector to the target and the projection of that vector onto the orbit plane

SSA - Angle between the sun and the target

ATTITUDE CONTROL/TELESCOPE POINTING

SUMMARY

- ET-GRIT ATTITUDE CONTROL REQUIREMENTS CAN BE MET
- MANEUVERING BETWEEN TARGETS CAN ACCOMPLISH MOMENTUM DUMPING OF THE CMG'S
- DURATION OF 30 MIN. MINIMUM TO DAYS PER TARGET IS FEASIBLE
- INFINITE NUMBER OF TIMELINE SCENARIOS ARE AVAILABLE
- UNIFORM GALACTIC PLANE COVERAGE CAN BE OBTAINED
- MAGNETIC TORQUER SYSTEM USED TO AUGMENT CONTROL
- COULD IMPLEMENT A TIMELINE SCENARIO TO MINIMIZE THERMAL CONTROL

Meteoroid/Space Debris Protection

ET-GRIT - Space Debris & Meteoroid Assumptions

- Liquid Hydrogen Tank Considered Only for the Exposure Area (600 M^2 & 470 M^2 Effective Exposure Areas for the Space Debris and Meteoroid Respectively)
- Meteoroid Environment Defined in NASA Sp 8013
  Density = 0.5 g/cc   Average Velocity = 20 km/s
- Space Debris Environment Defined in JSC 20001
  Density = 2.8 g/cc   Average Velocity = 9 km/s
- NASA Sp 8042 Used for Penetration of Single Sheets
- 5 Year Exposure Duration
- Orientation - Pointing to a Point at Infinity Lying in the Orbital Plane During a Complete Orbit
- Altitude Of 220 Nm (400 km) - Used in Analysis

ET-GRIT - Light Gas Gun Tests - 1987

OBJECTIVE

- Examine Foam Cratering
- Compare Penetration Resistance of Samples with Foam to Samples without Foam

APPROACH

- Impact Foam Samples with 0.125" Aluminum Spheres
  - Record Volume of Foam Removed vs Energy
    (Meteoroid Simluation was Not Possible)
- Impact Bumper Specimens with 0.25" Aluminum Spheres
  - 0.063" Bumper; 3 inch Gap; 1 inch CPR 488 on 0.125" 2219
  - Determine Ballistic Limit Between 3 and 6 km/s
  - Compare to Space Station Test Samples

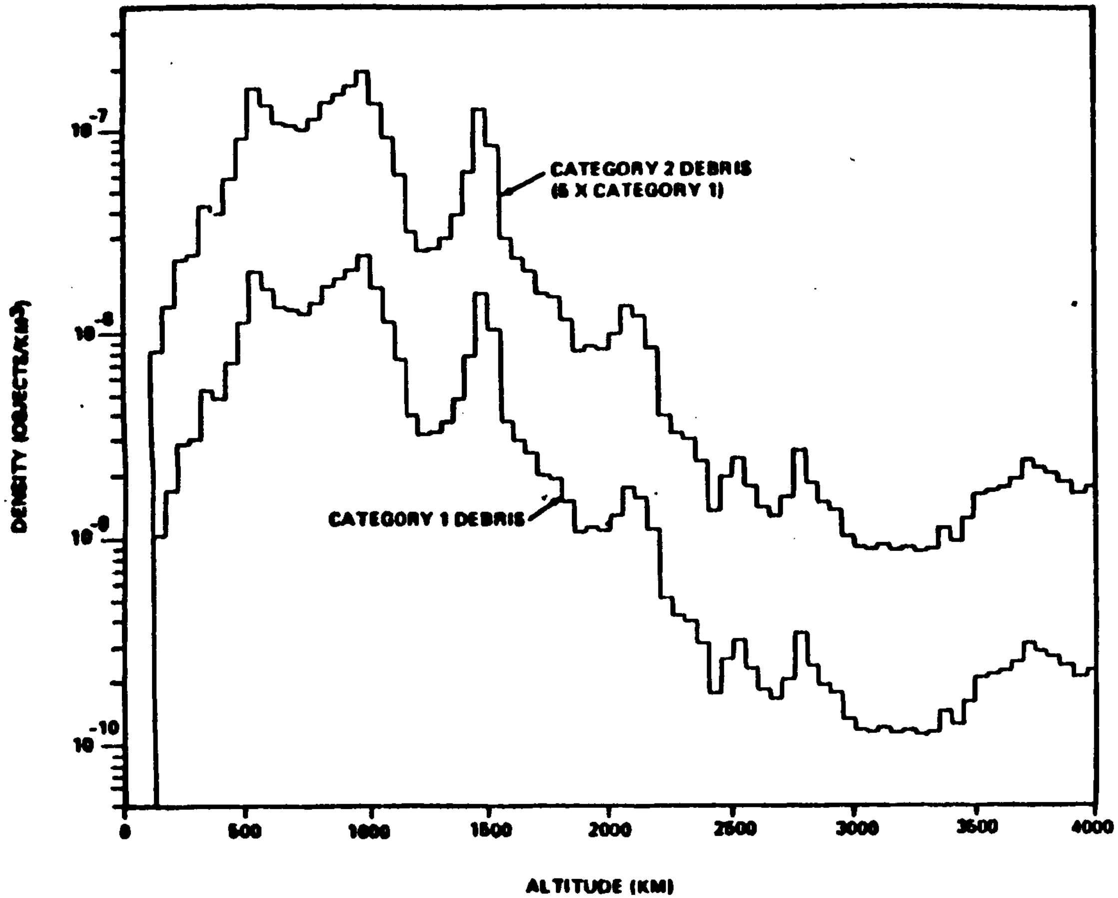
RESULTS

- 2 to 30 Cubic Inches of Sofi Removed in Single Impact
  - Failure Occurred in Foam and Not at Al Interface
- Ballistic Limit with Bumper Approximately 5 km/s
  - As Good as SS Samples with Beta Cloth and MLI
  - Better than Plain Bumper and Rear Wall - Ballistic Limit > 7 km/s

MARTIN MARIETTA
MANNED SPACE SYSTEMS

ffb#3

ET-GRIT - Density of Tracked Space Debris

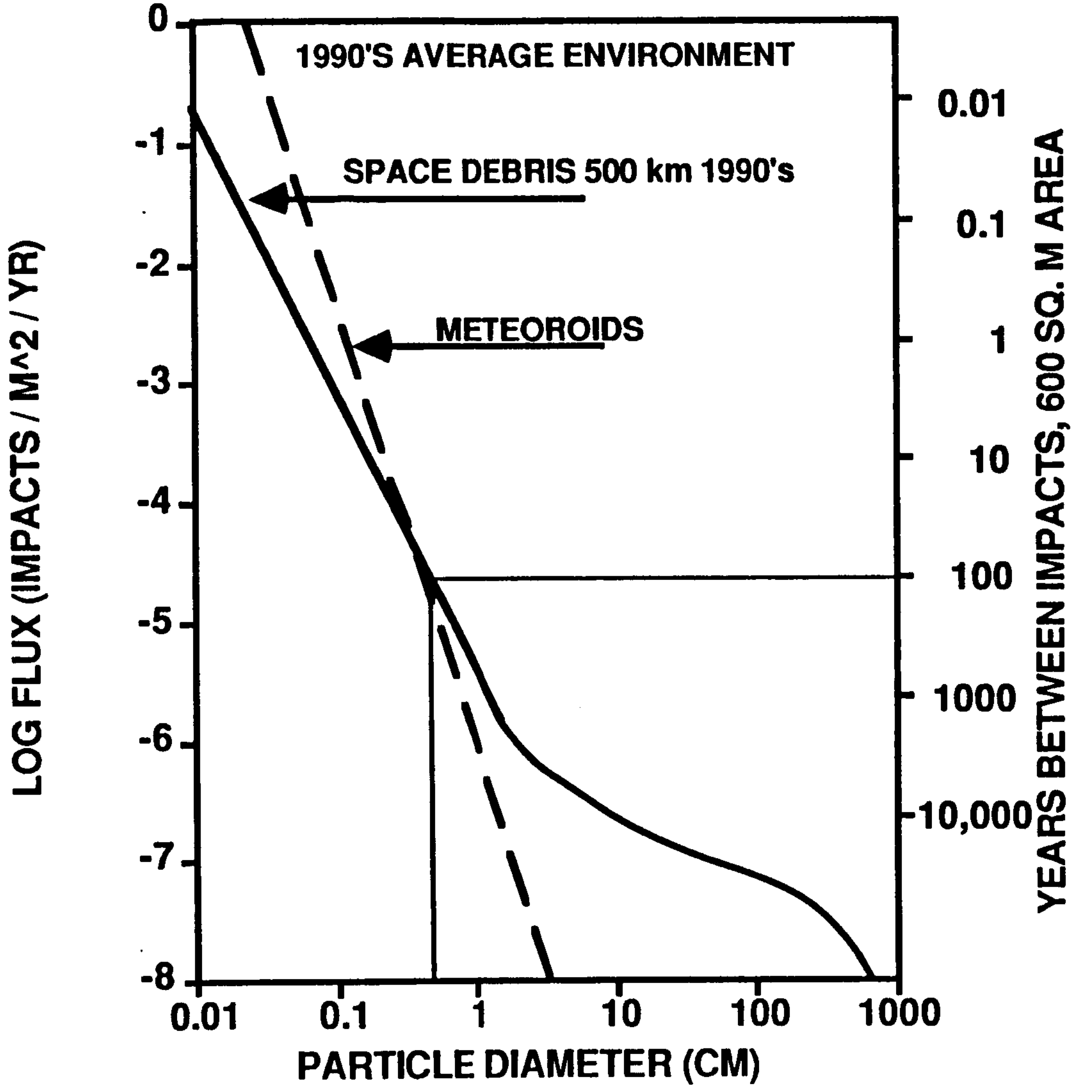


CATEGORY 1. TRACKED BY NORAD

CATEGORY 2. UNTRACKABLE BETWEEN 1 MM. AND 4 CM.

MARTIN MARIETTA
MANNED SPACE SYSTEMS

ET GRIT - Flux vs Diameter Relationship



REFERENCES:

JSC 20001

JSC30000
Appendix 3.1

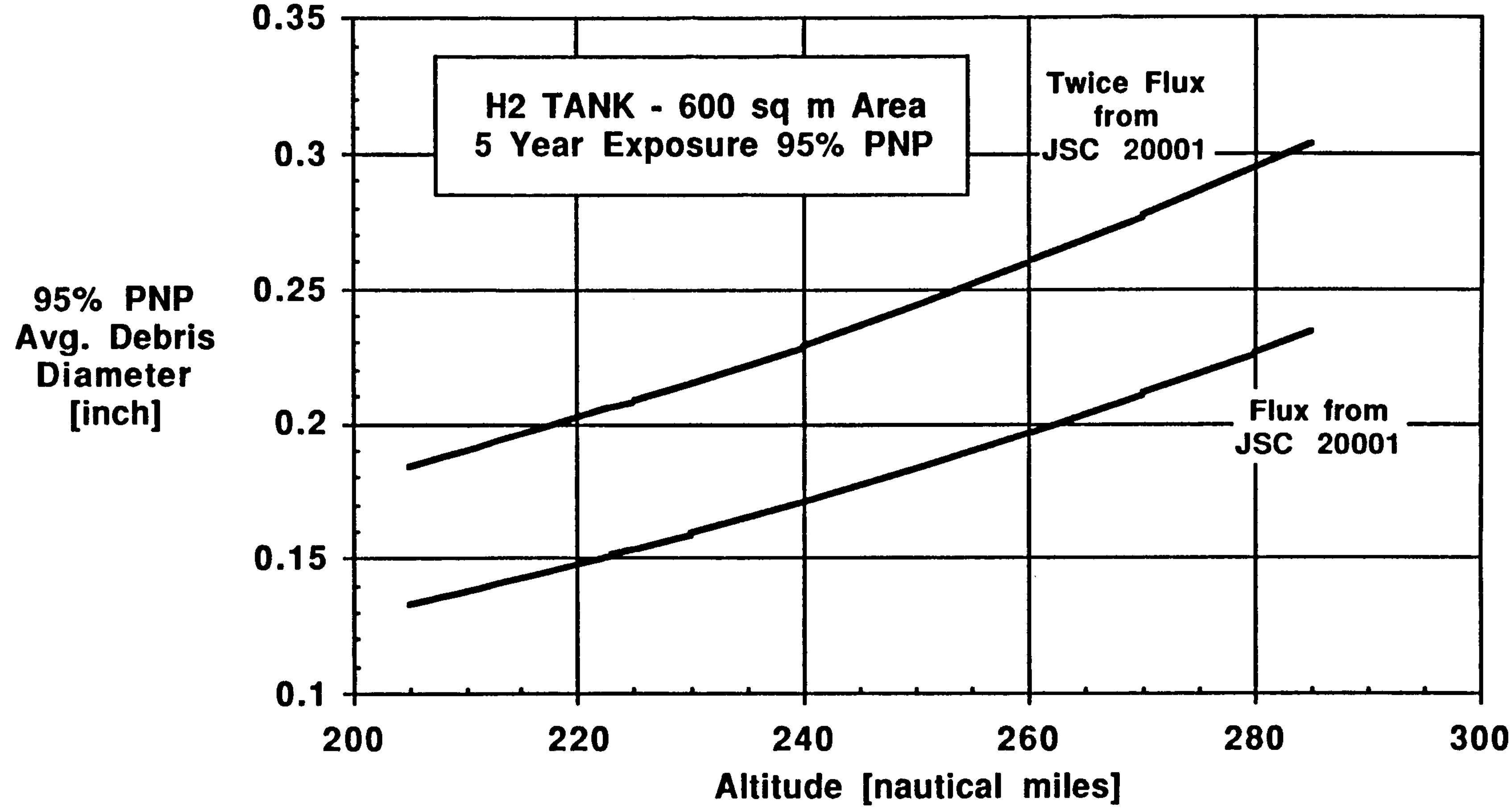
Average Velocity

Meteoroids
20 km/s

Space Debris
10 km/s

MARTIN MARIETTA
MANNED SPACE SYSTEMS

ET-GRIT - Debris Size vs Altitude



MARTIN MARIETTA
MANNED SPACE SYSTEMS

ET-GRIT - Space Debris & Meteoroid Issues

- Penetration Resistance - 1987 Analysis
  - Proposed Requirement - 95% Probability of No Penetration (PNP) in 5 Years
    Mean Time Between Failures (MTBF) = 100 Years
  - Bumpers Required to Meet PNP Requirement

- Penetration Resistance - 1988 Analysis
  - Improved Penetration Analysis
    - Altitude
    - Update Debris Environment (Expect 2x Increase)
    - Velocity and Obliquity Effects
    - Trade Studies

- Minimizing ET-GRIT Contributions to Debris Environment - 1988 Analysis
  - Predicted Meteoroid and Debris Impacts
    - Hazards of TPS
    - Orbital Decay of TPS Debris
    - Containment
  - Improbable Debris and Meteoroid Impacts
    - Removal of Untrackable Debris
    - Risk of Complete Penetration of ET

ET-GRIT Penetration Size And Rate

- Assuming The Hole Radius Is Equivalent To The Crater Depth Made In A Semi-infinite Body (NASA SP 8042).

FOR 0.15 ins THICK ALUMINUM

Hole Diameter	Space Debris Penetrations/Year	Meteoroids Penetrations/Year	Total Penetrations/Year
UP to 0.5 cm	0.205	1.148	1.353
0.5 to 1.0 cm	0.137	0.219	0.356
1.0 to 1.5 cm	0.021	0.017	0.038
1.5 to 2.0 cm	0.007	0.003	0.010
2.0 to 4.0 cm	0.006	0.002	0.007
> 4.0 cm	0.001	0.000	0.002

ET-GRIT Probability Of No Penetration

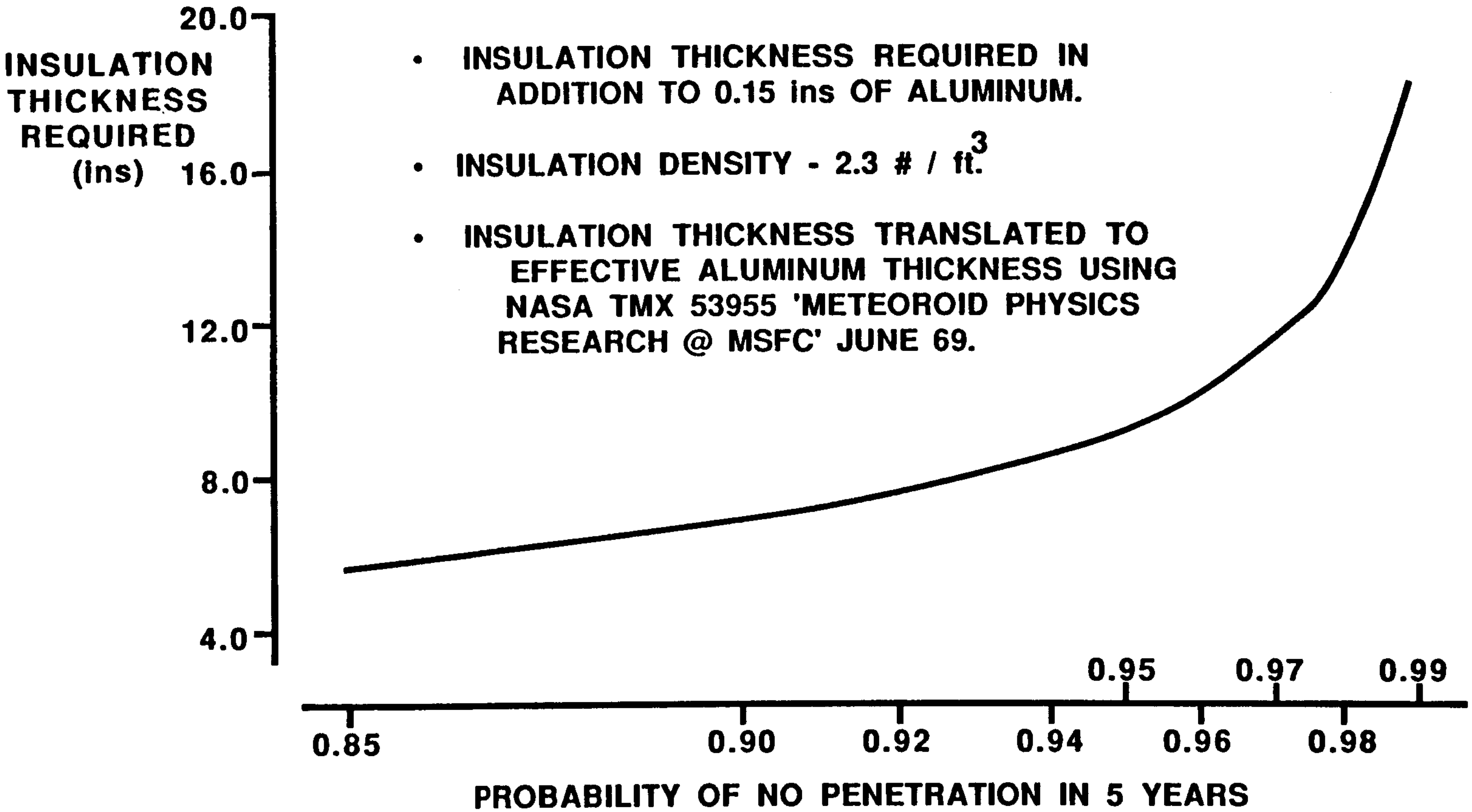
- RESULTANT PROBABILITY OF NO PENETRATION WITHOUT ANY ADDITIONAL SHIELDING ADDED.

	Meteoroid Probability Of No Penetration	Space Debris Probability Of No Penetration	Total Probability Of No Penetration
WITHOUT INSULATION (0.15 in Thick)	0.0008	0.1511	0.0001
WITH INSULATION (0.236 in Effective Thick)	0.2255	0.5131	0.1157

Space Debris/Meteoroid Protection Design Candidates

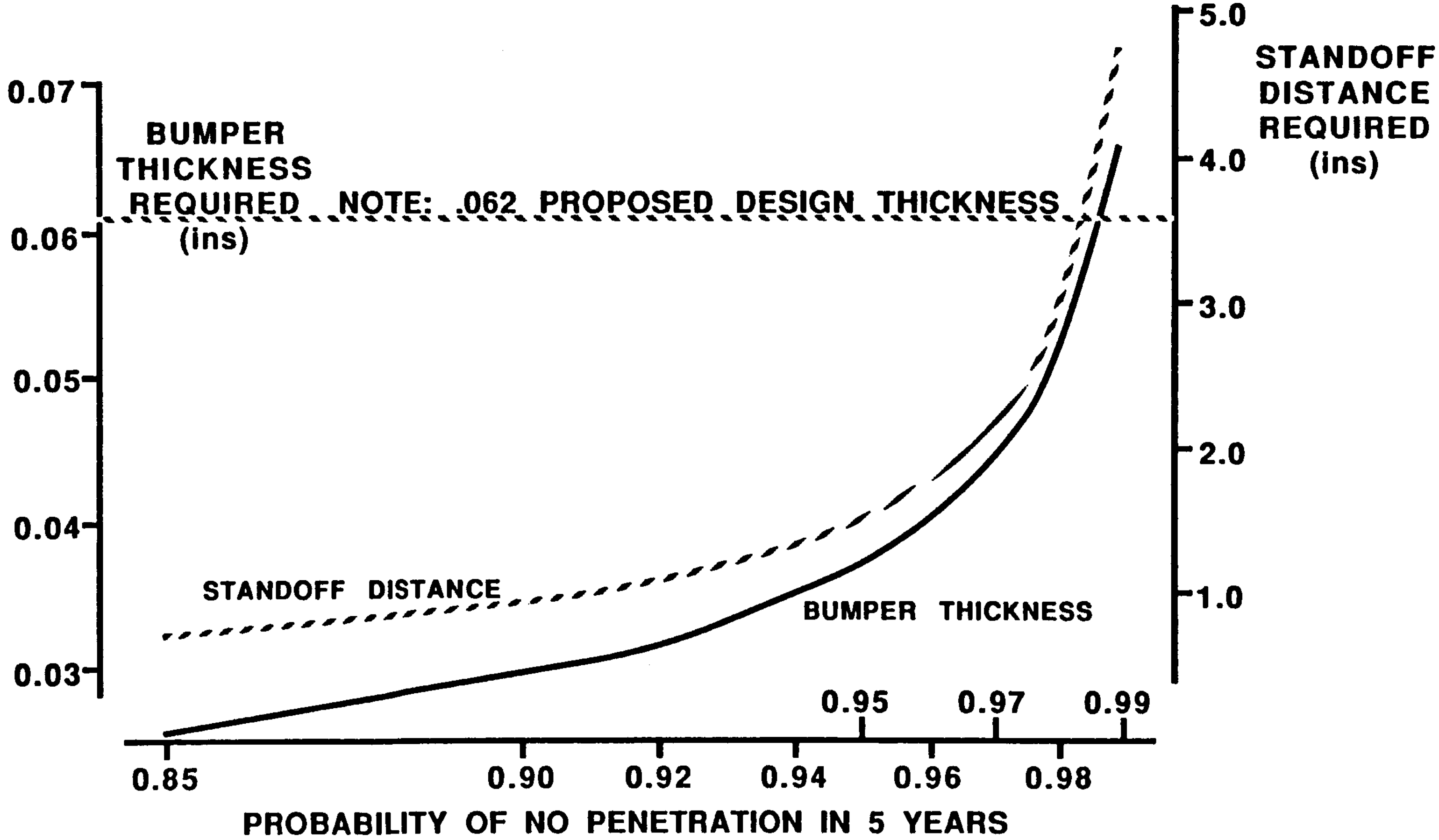
System Candidates	Comments
• No Meteoroid Protection	- More Frequent Revisits For Onorbit Repair And Pressurization Gas Refurbishment - No Weight Impact To ET
• Additional Or New ET Insulation	- Requires Assessments For ICD Reqmnts, Aerodynamic Considerations, Weight Impacts, Survival To Orbit - Application/Materials Require Development - No EVA Req'd For Installation
• Ground Installed Bumper System	- Design Must Withstand Launch Environment - Weight Impact To ET - Assessment Of ICD Requirements - No EVA Required For Installation
• Onorbit Installed System	- Requires Assessments For EVA Assembly Methods, EVA Timelines, Available Volume In Cargo Bay For System Components - Lighter Weight Than A Similar Design Installed On Ground

ET-GRIT Insulation Shield Required



ET-GRIT Bumper Shield Required

- REAR WALL THICKNESS TAKEN AS 0.15 ins OF ALUMINUM.

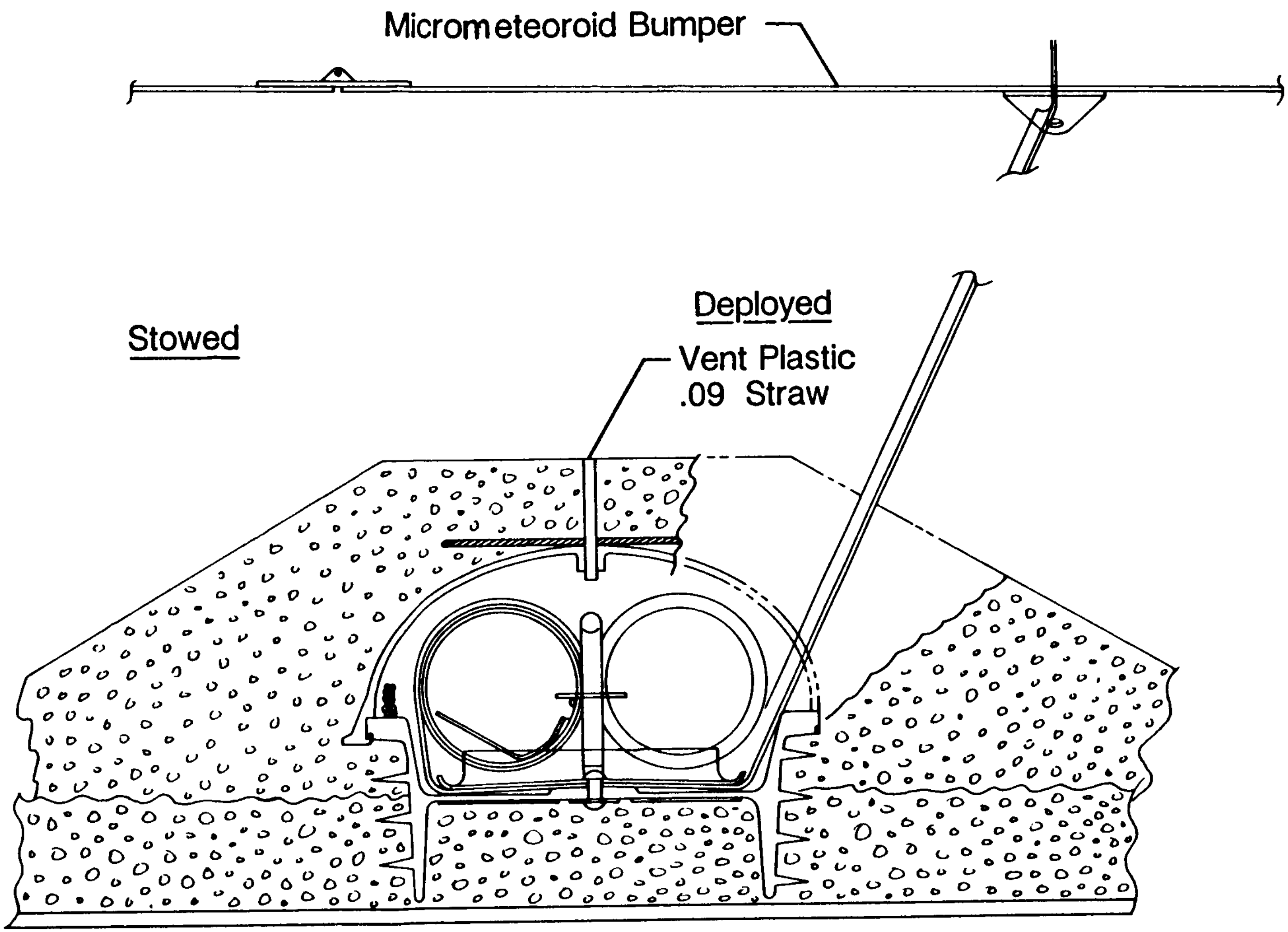


MARTIN MARIETTA
MANNED SPACE SYSTEMS

ET-GRIT Micrometeoroid/Debris Protection Concept

- 0.062" Aluminum Bumper Shield
- 156 Support Anchors
- Anchors Stowed in Islands During Ascent
- Anchors Deployed Onorbit by EVA
- Shield Carried in Orbiter Bay and Installed Onorbit by EVA
- Total Mass ~ 8,000 Lbs
  - 7800 Lbs Shield
  - 200 Lbs Anchor Islands

ET-GRIT Micrometeoroid/Debris Protection Concept



Neutral Buoyancy Simulations

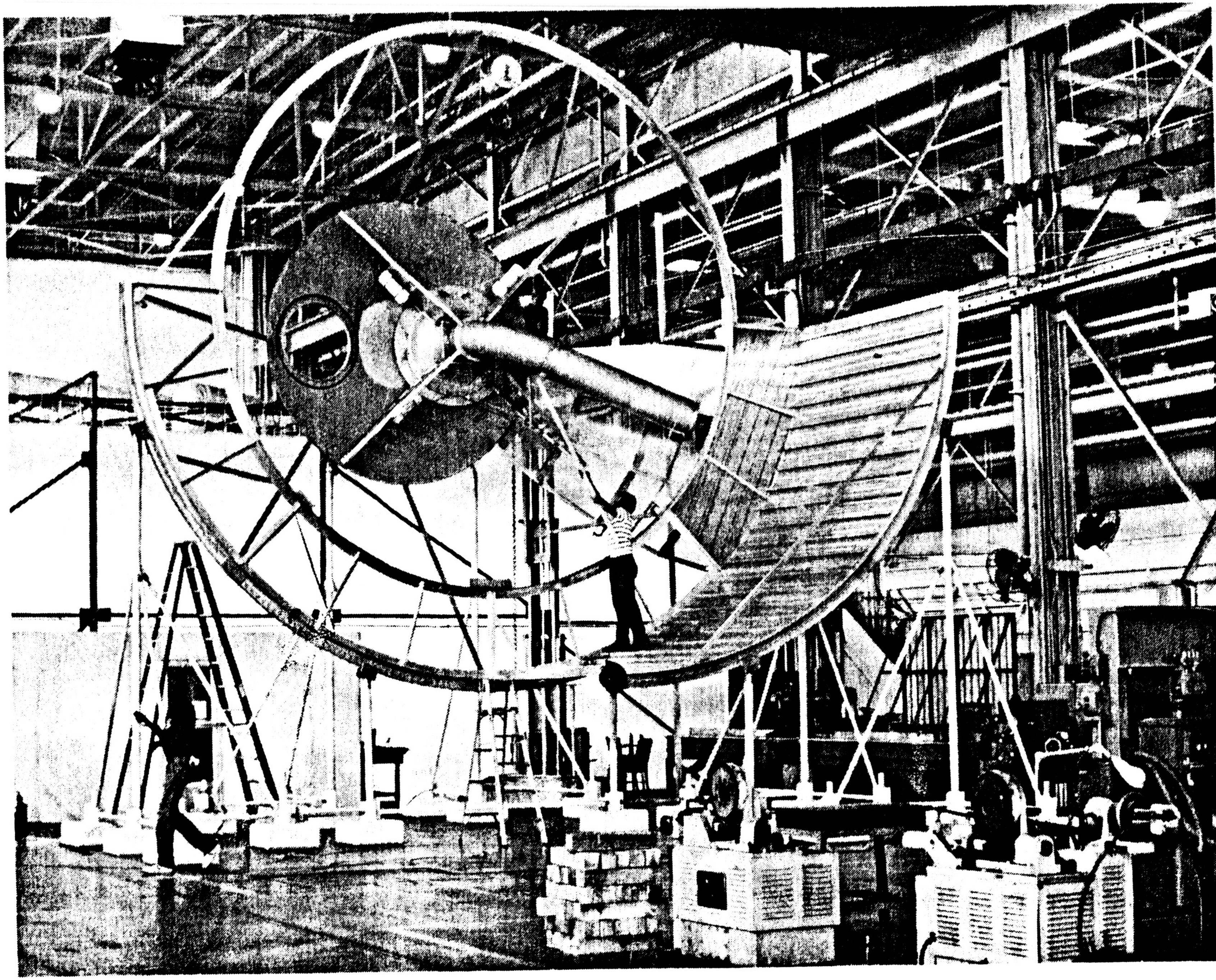
MARTIN MARIETTA
MANNED SPACE SYSTEMS

ET-GRIT Neutral Buoyancy Test Objectives

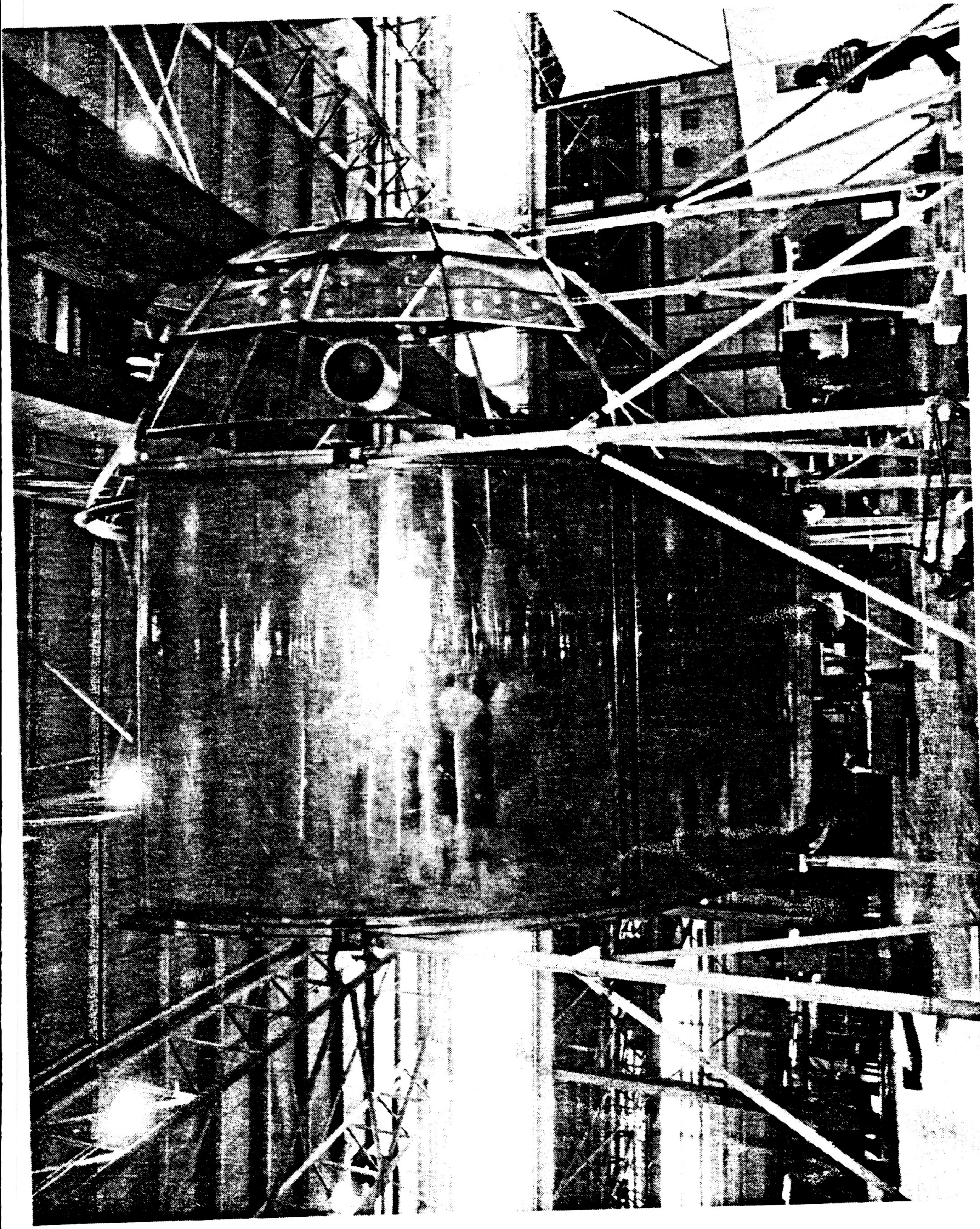
- Siphon Removal Timelines
- LH2 Tank Handhold, Foot Restraint, and Access Enhancements
- Improved TPS Removal Demonstration
- Mirror Installation
- LH2 Tank Manhole Cover Pivot Demonstration

LH2 Tank Simulator Major Components

- Aft End Dome Cap
- 45º Simulated Dome Segment
- 2058 Ring Frame
  - 180º Fully Simulated Ring
  - 180º Simulated Inboard Ring
- 90º LH2 Barrel Section
- LH2 Siphon Assembly

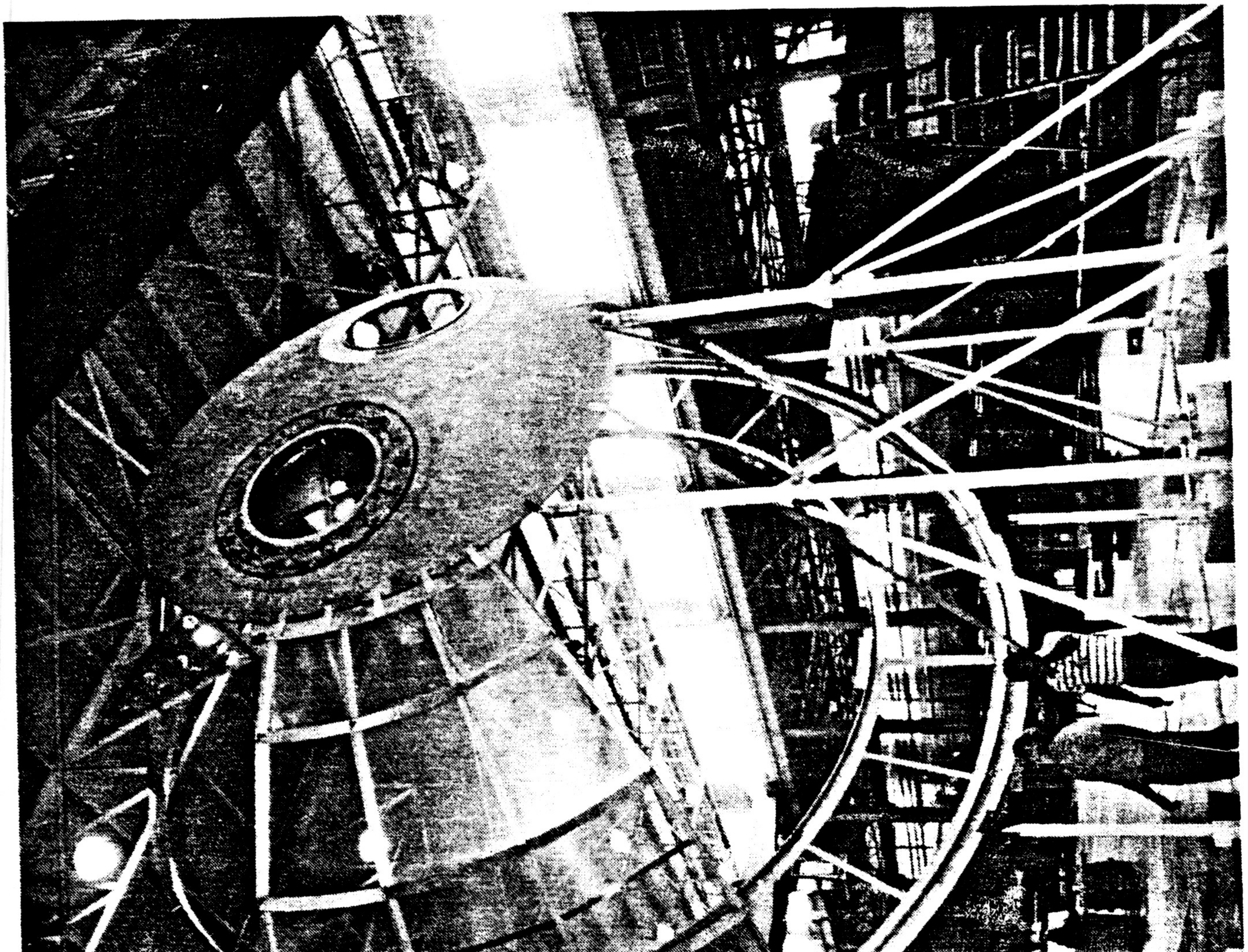


LH2 Tank Simulator Front View



LH2 Tank Simulator Side View

ORIGINAL PAGE IS
OF POOR QUALITY



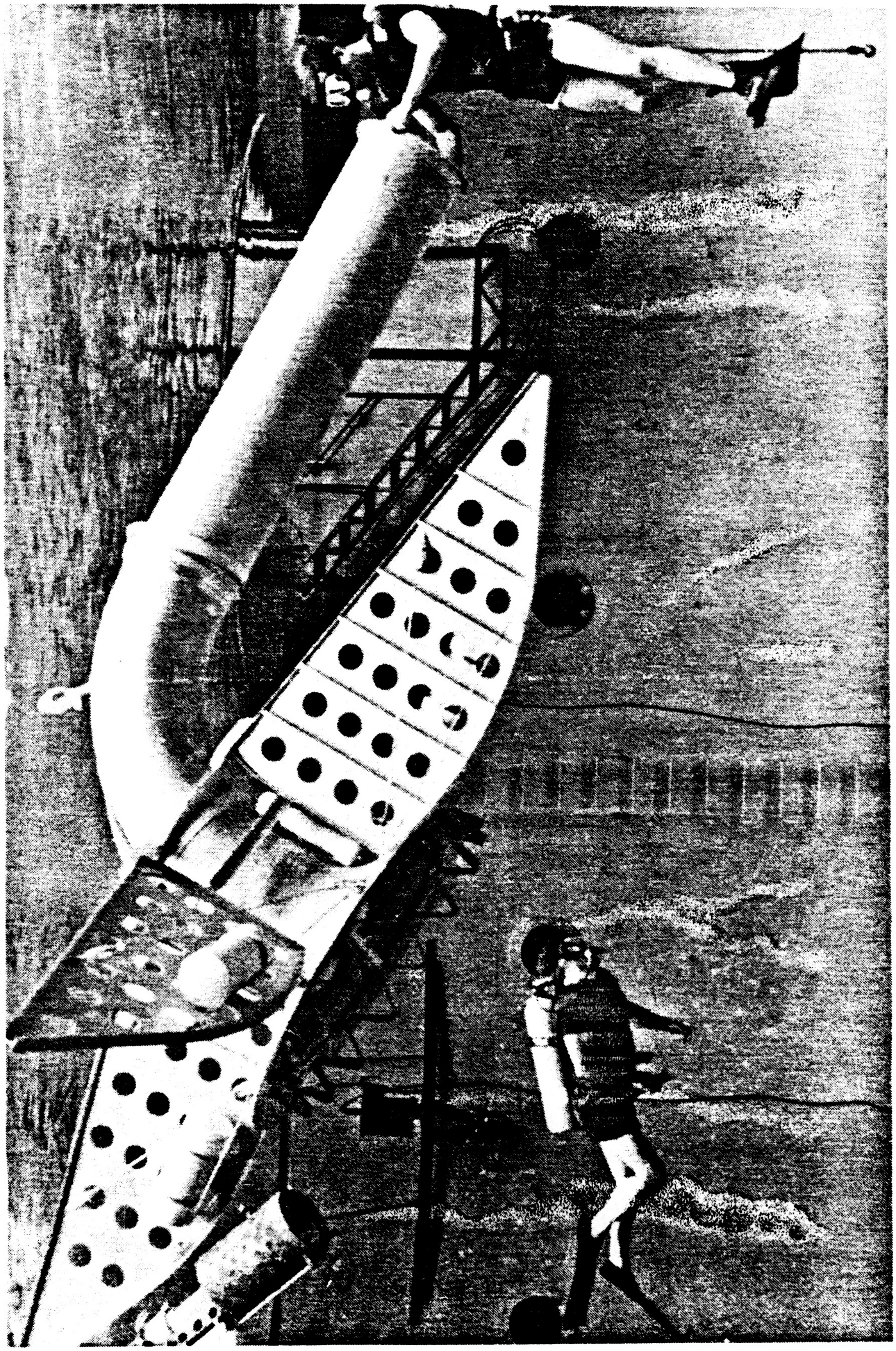
LH2 Tank Simulator Aft View

Neutral Buoyancy Calculations of LH2 Siphon

	Wt. (Lbs)	X (In)	Y (In)	Z (In)
Fence Installation	9.8	0.0	0.0	2.5
Baffles and Installation	71.8	0.0	0.0	20.0
Siphon	72.7	0.0	0.0	10.0
Elbow	31.9	0.0	0.0	50.5
Pipe	40.9	0.0	71.7	65.0
Baffle Attach Frame	6.0	0.0	2.5	38.0
Siphon Support Frame	14.0	0.0	0.0	5.0
	247.1	0.0	11.9	27.3

LH2 Siphon Assembly Neutrally Buoyant

- 3 inch PVC Pod Horizontally Attached to Each Baffle
- 3 inch PVC Pod Vertically Attached to Siphon Tube Near Bell Portion
- (3) 6 inch PVC Pods Inserted and Secured in Siphon Bell
- 1 1/2 lbs Lead Weight Attached in the Siphon Tube Opening



LII2 Siphon Assembly

ET-GRIT NBS Test Duration

- 6 Days for Assembly of Simulator in NBS Tank
- Tests Conducted October 14, 19, 21, 28, 29 and November 4 and 5, 1987
- 4 Days for Disassembly of Simulator in NBS Tank

ET-GRIT NBS Test Outline

- Introduction
- Scope
- Purpose
- Objectives
- Test Summary
- Test Description
- Test Briefing
- Equipment Setup
- Test Equipment
- Tool/Support Equipment
- Initial Test Setup
- Test Procedures
- Synopsis
- Data Recording Requirements
- Safety Analysis
- Emergency Procedures

Demonstrated EVA Enhancements

- Aft Manhole Cover Bolt TPS Removal
- LH2 Tank Ingress "Firemans Pole"
- LH2 Tank Handhold and Foot Restraint Concepts
- LH2 Tank Siphon Removal Enhancement

Requirements for TPS Removal Onorbit

- Onorbit, Weightless Capability
- Minimize Uncontrolled Debris Generation
- Maintain Pre-Launch and Ascent TPS Requirements

Machined Phenolic Composite Ring Concept

Description:

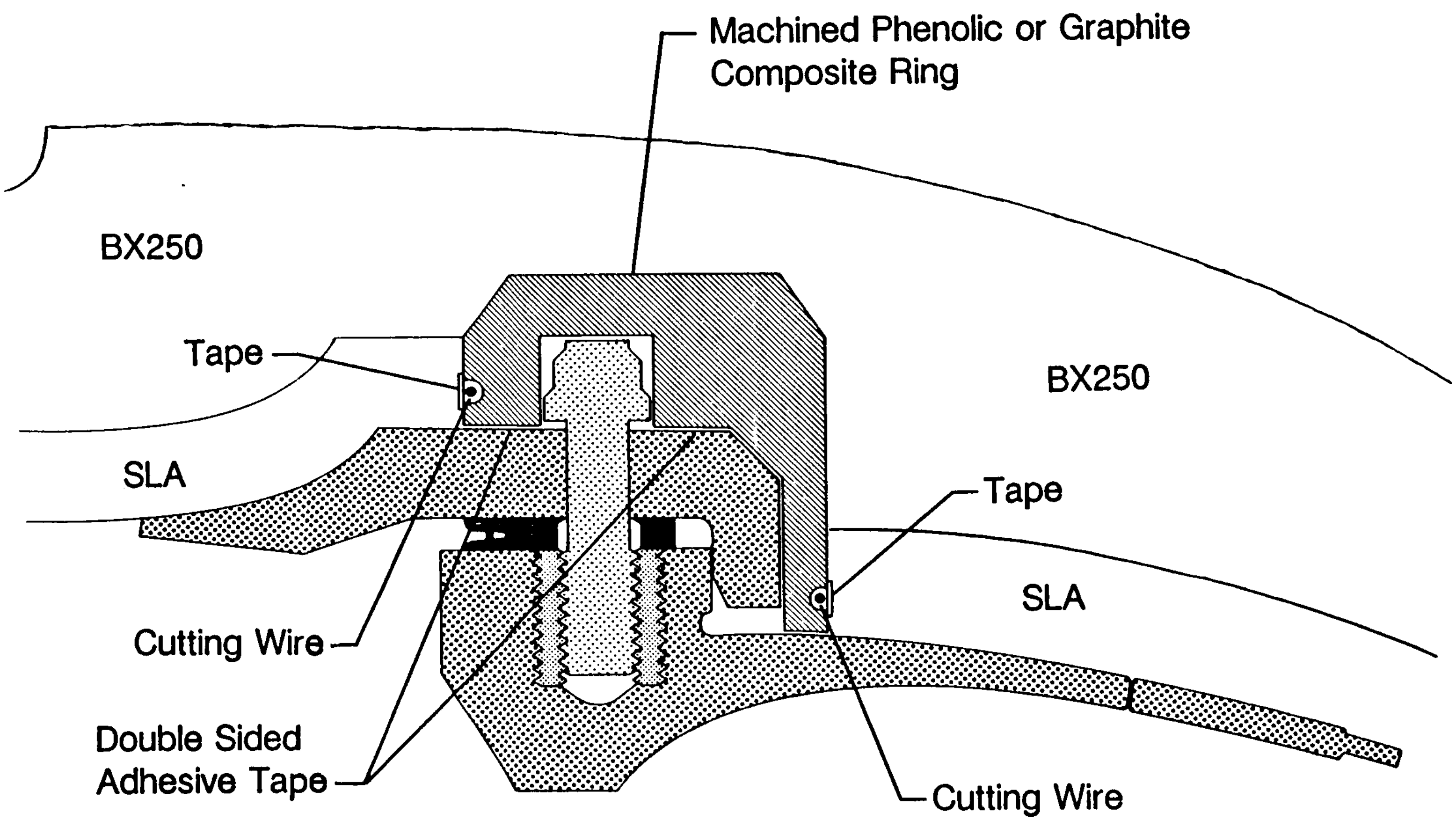
- Fabricate a Phenolic Ring Which Will Mate Over the Manhole Cover Bolt Flange

- Machined Ring Incorporates Two Stainless Steel Cutting Wires Located on the Inside and Outside Circumferences. Pull Handles for the Cutting Wires Are Color Coded

- Before TPS Application, the Ring Is Located on the Manhole Cover. TPS is Then Applied Covering the Manhole Cover Access Ring

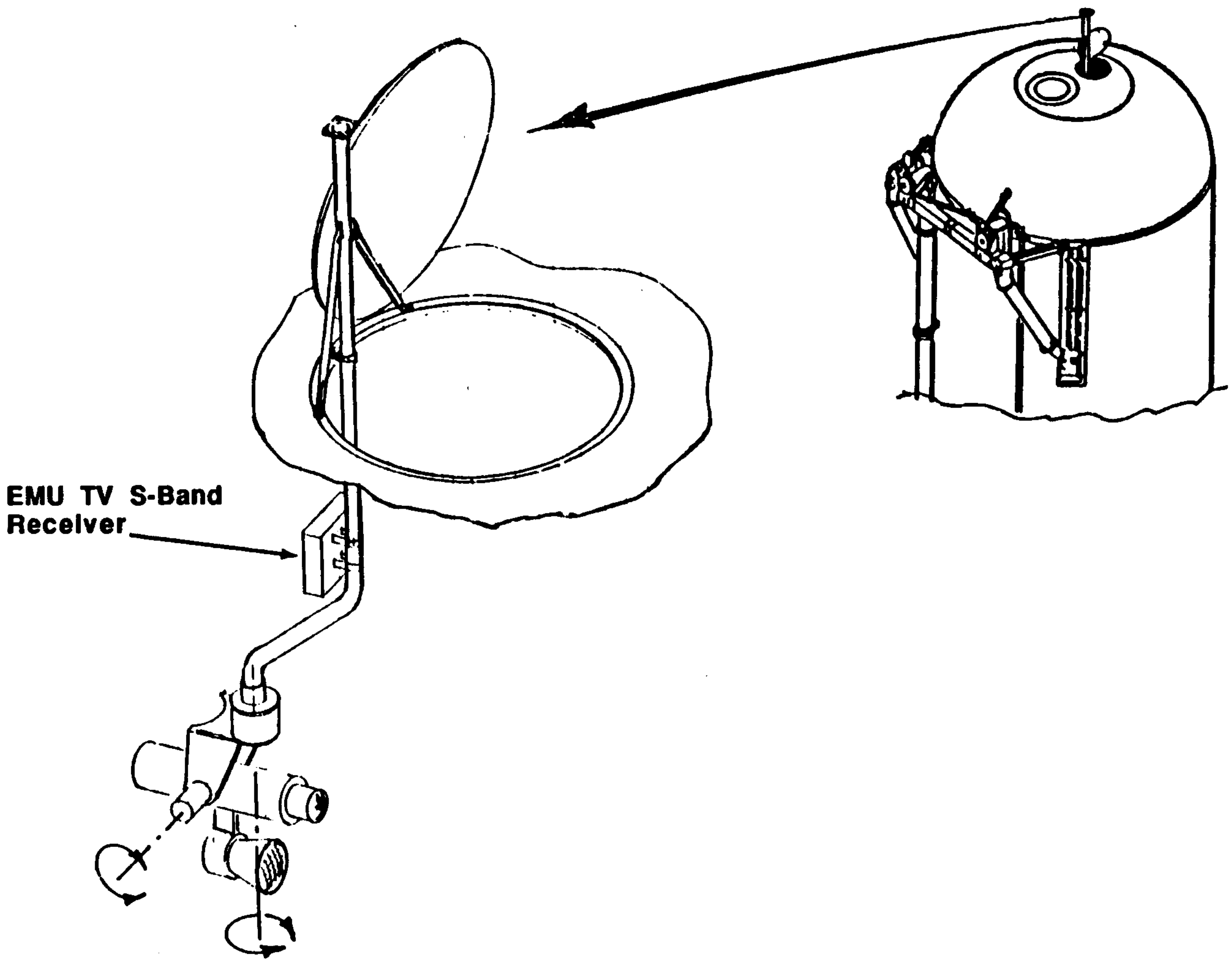
- While Onorbit, Astronauts Remove Foam From Above the Pull Handle Storage Areas. Once the Handles Are Accessed, the Manhole Cover Access Ring Is Removed by Pulling the Inside and Outside Cutting Wire Handles, Cleanly Cutting the Foam Around the Ring Circumferences. The Ring Is Removed Enabling Clean and Easy Access/Removal of the Manhole Cover Bolts and Manhole Cover.

TPS Removal Concept



MARTIN MARIETTA
MANNED SPACE SYSTEMS

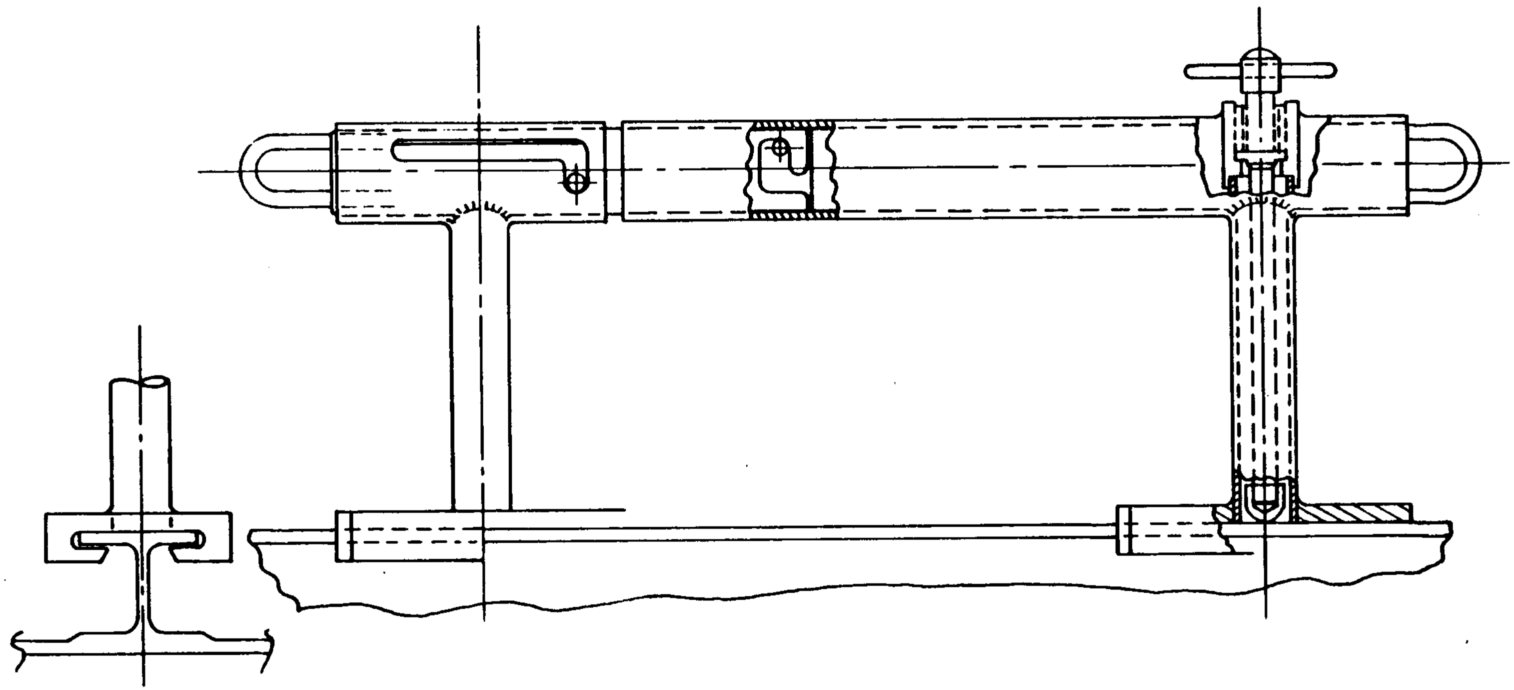
LH2 Tank Entry



MARTIN MARIETTA
MANNED SPACE SYSTEMS

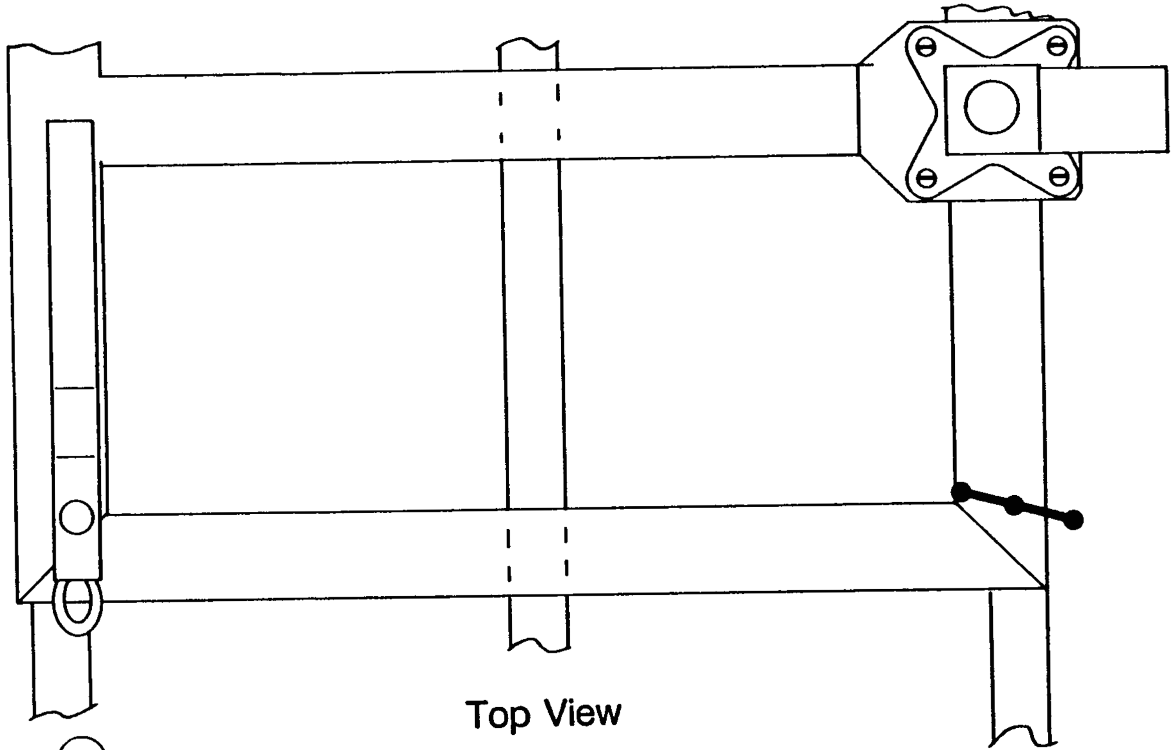
05AVP987

LH2 Tank Handhold

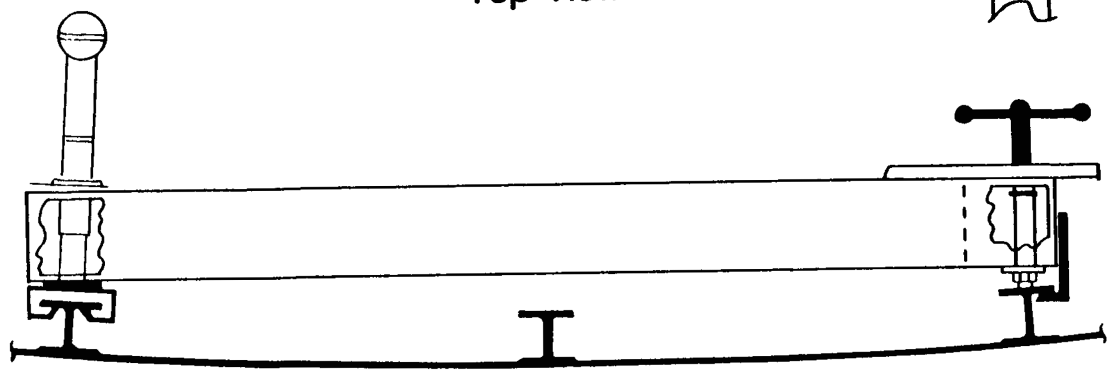


MARTIN MARIETTA
MANNED SPACE SYSTEMS

LH2 Tank Foot Restraint Assembly Adaptor



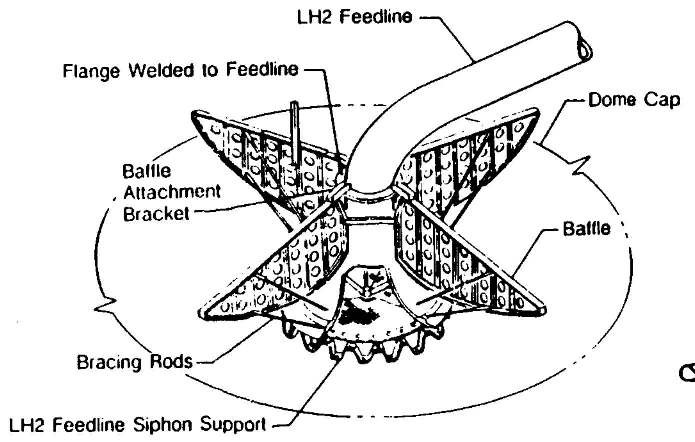
Top View

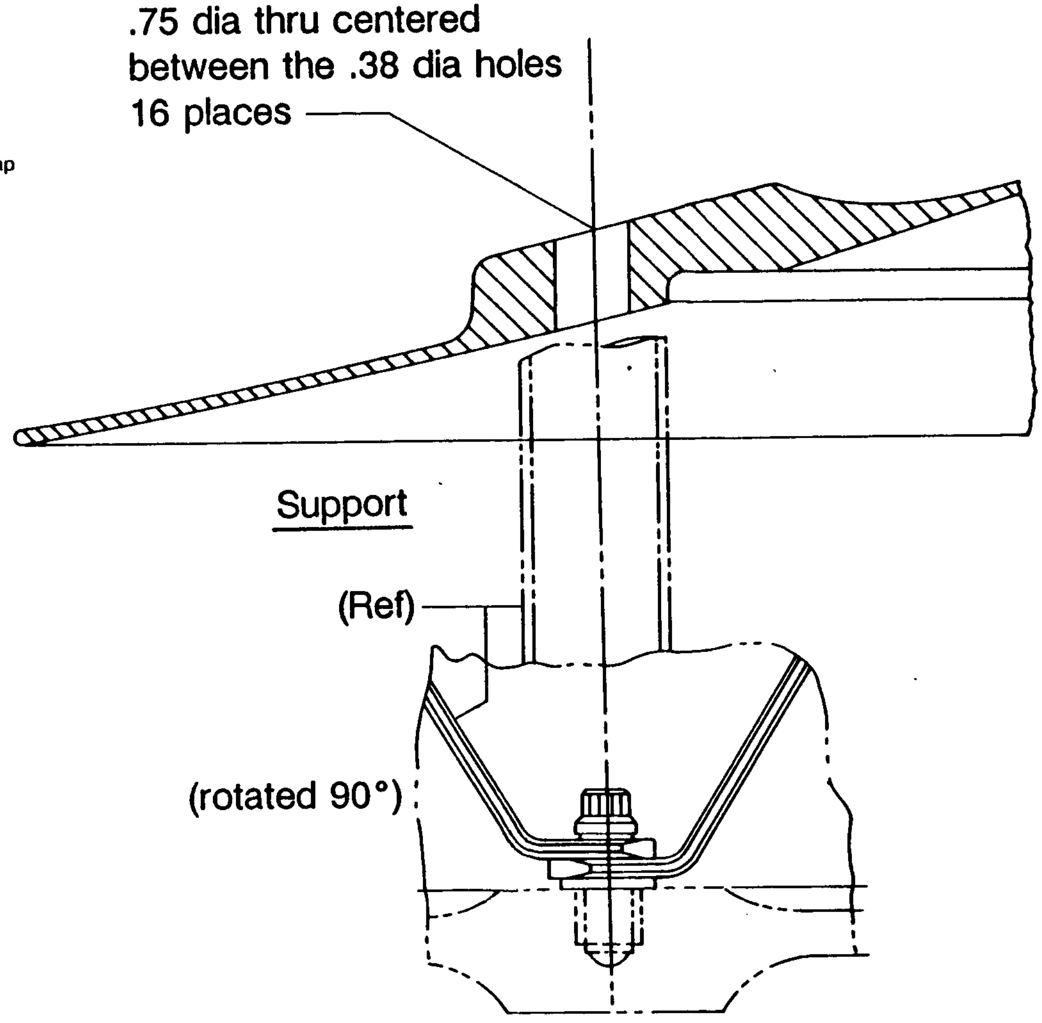


Side View

MARTIN MARIETTA
MANNED SPACE SYSTEMS

LH2 Siphon Modification for ET-GRIT





MARTIN MARIETTA
MANNED SPACE SYSTEMS

LH2 Siphon Assembly Removal Demonstration

<u>Tools Used</u>

- Pneumatic Air Impact Wrench - 3/8" Drive
- Air Impact Wrench Extension
- Breaker Bar
- (2) Box-End Wrenches Modified with Hand Sleeves (1 inch Diameter) and Tether Rings

<u>Pretest Modifications to the Flight Hardware</u>

- 16 Additional Drilled Bolt Holes in Siphon Bell

<u>Process</u>

- Attach Tether Line from Fireman's Pole to Forward Area of the LH2 Tank
- Secure Foot Restraint Platform and Mount Foot Restraint
- Break Flight Required 700 in-lb Torque of Siphon/Bellows Flange - 5/16 Bolts; Not Hindered by H-Frame Bracket
- Unbolt and Remove H-Frame Bracket
- Complete Breaking the Torque of Siphon/Bellows Flange Bolts
- Remove 3/8 inch Bolts Joining the Siphon Fence to Dome Using Air Wrench
- Move Siphon Assembly to Forward Dome Area Using the Tether Line
- Secure Siphon Assembly

LH2 Siphon Assembly Removal Demo., cont.

<u>Recommendations</u>

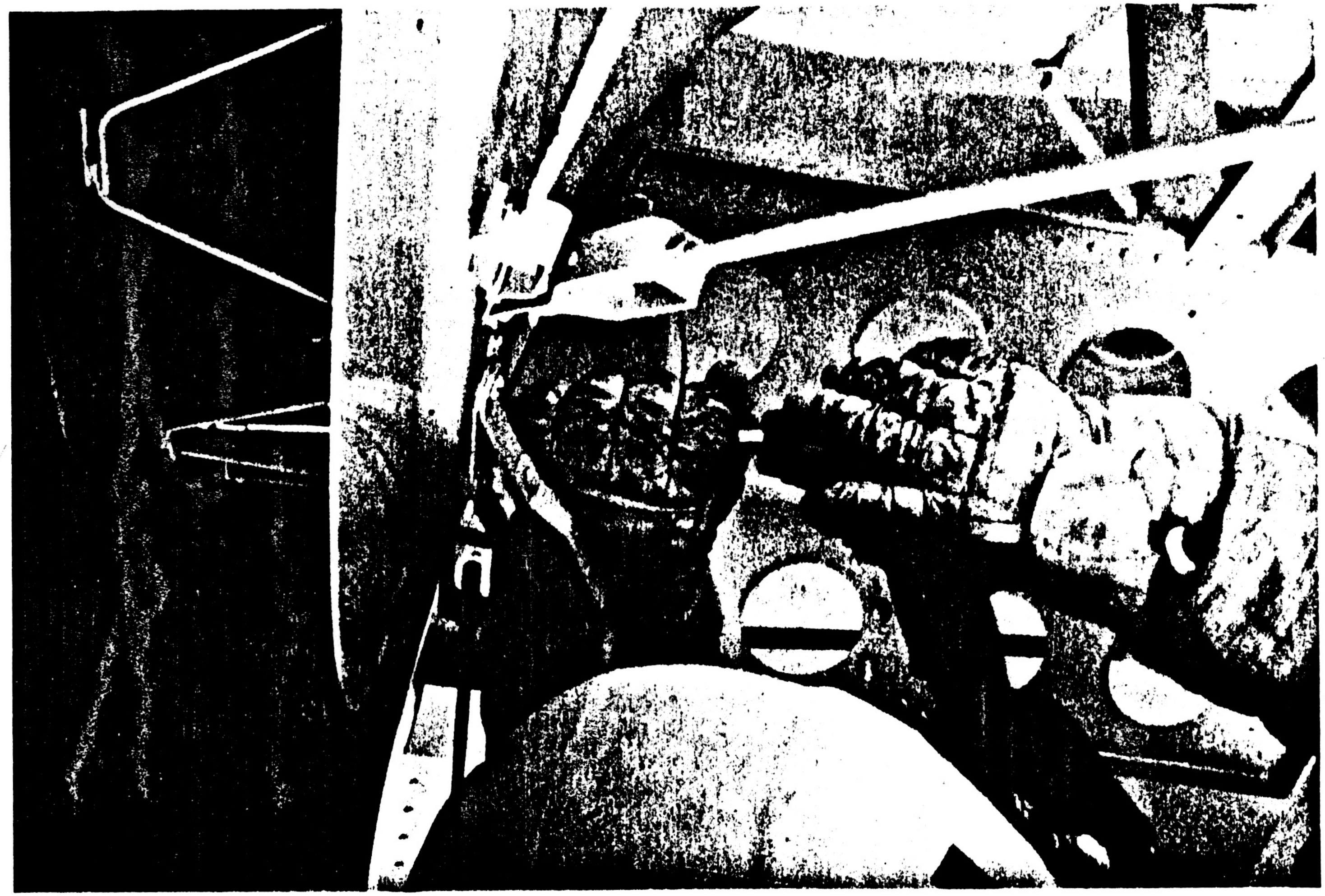
- Change Flange Nuts to Nut Plates or Keen Serts
- Change Siphon Bolts to Captured Bolts
- Remove the Final Bolt on the Siphon Fence Closest to the Fireman's Pole
- Install Breakaway Material Over Manhole Opening Prior to Siphon Assembly Removal
- Astronauts Work Together on Each Task to Assist on Body Positions for Bolt Removal

LH2 Siphon Bolt Removal at Flange

ORIGINAL PAGE IS
OF POOR QUALITY

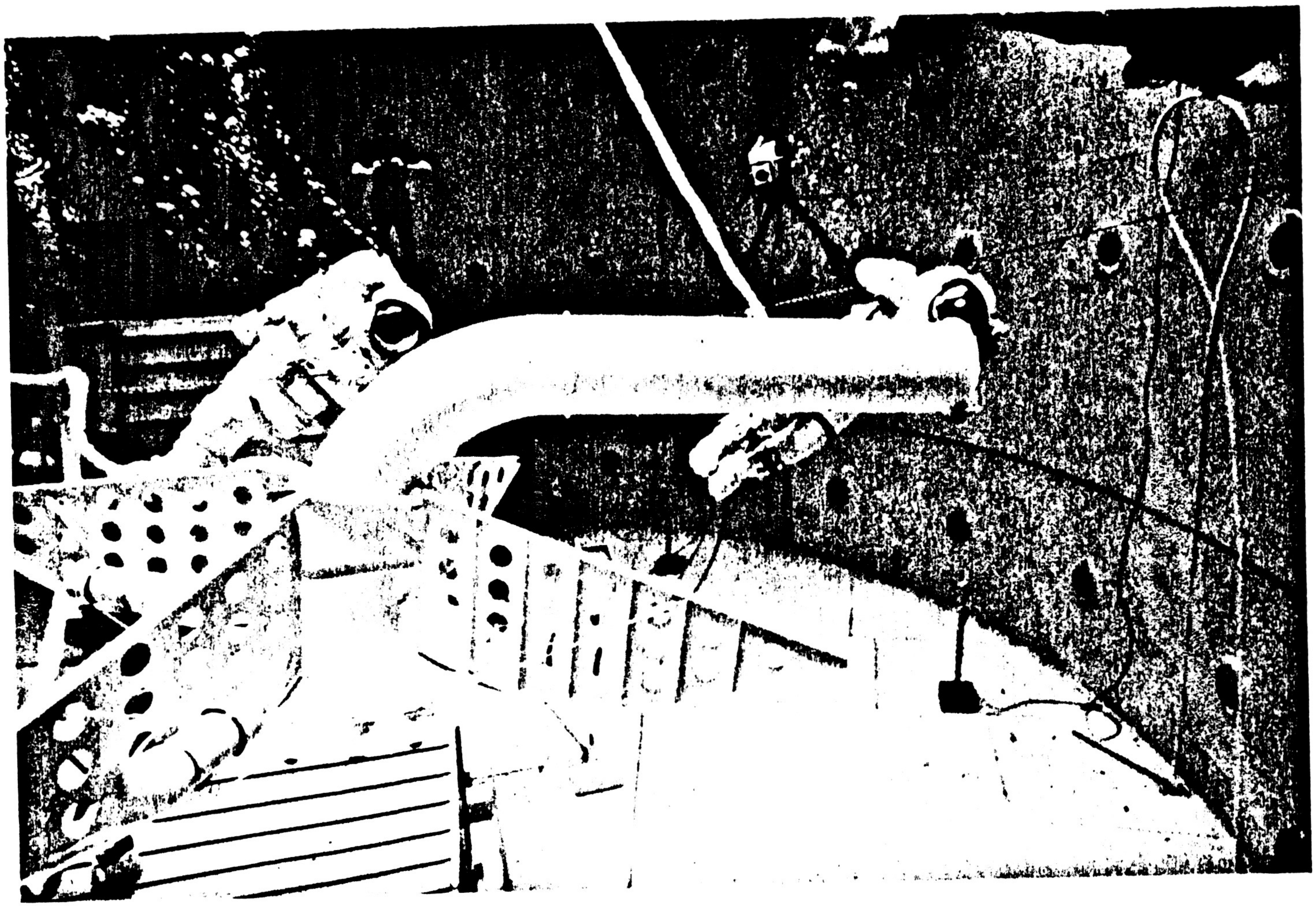
6

LH2 Siphon Bell Removal from Dome Cap



MARTIN MARIETTA
MANNED SPACE SYSTEMS

LH2 Siphon Assembly Ready for Stowage



8

MARTIN MARIETTA
MANNED SPACE SYSTEMS

EVA Foot Restraint Platform Demonstration

Tools Used

- None

Pretest Modifications to Flight Hardware

- None

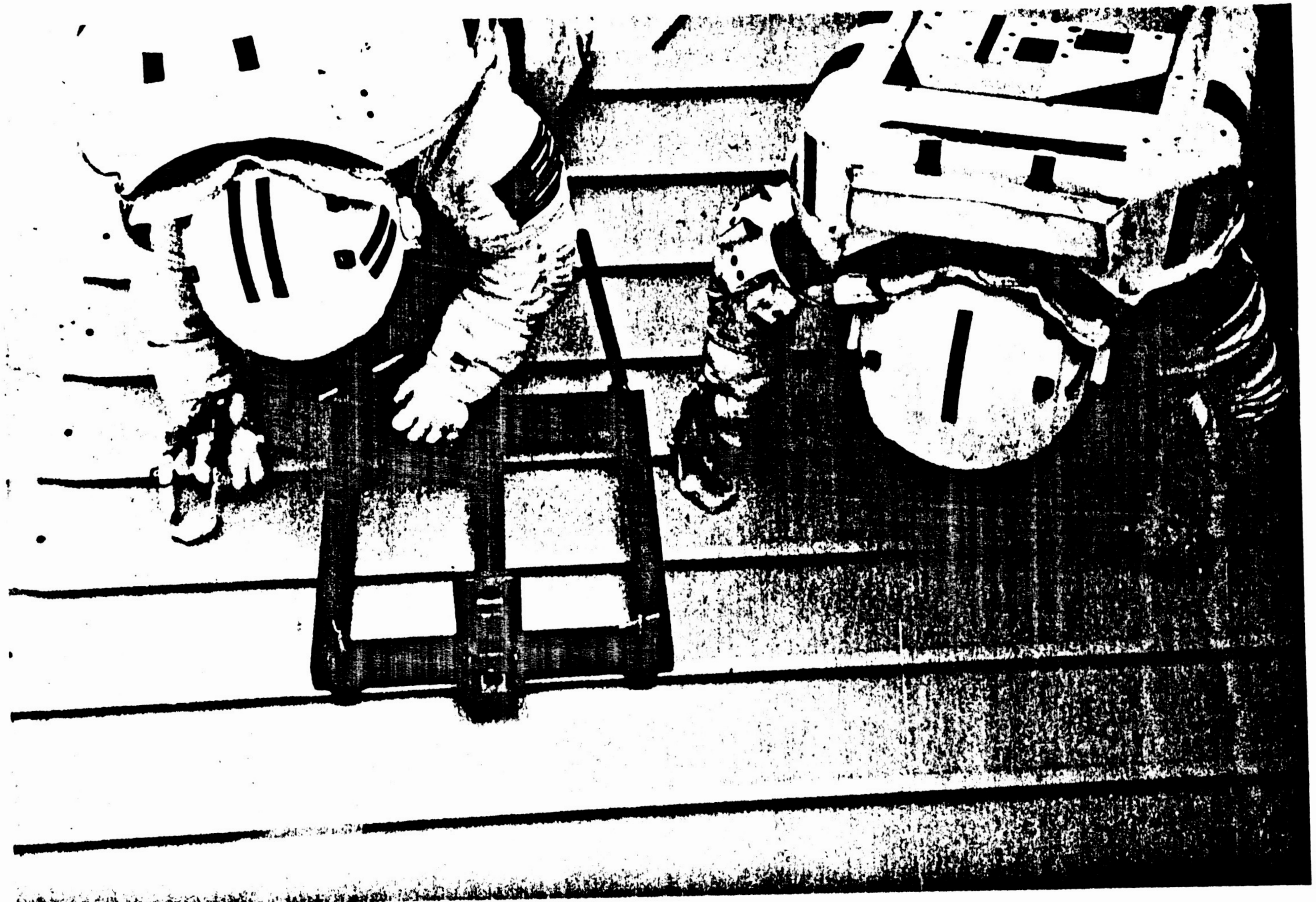
Process

- Place Foot Restraint Platform on LH2 T-Stiffeners
- Secure and Lock in Place
- Mount EVA Foot Restraint onto Platform

Recommendations

- Add Arched Handhold to the Center Line of the Platform or Modify the Center Line of the Platform by Flipping it 360° for the Handhold
- Modify Platform with a "Stop" Across from the Angle that Fits Underneath the Lip of the T-Stiffeners
- Replace the Bolt Latch with a Collar or Sleeve on the Outside

Installation of EVA Foot Restraint Platform

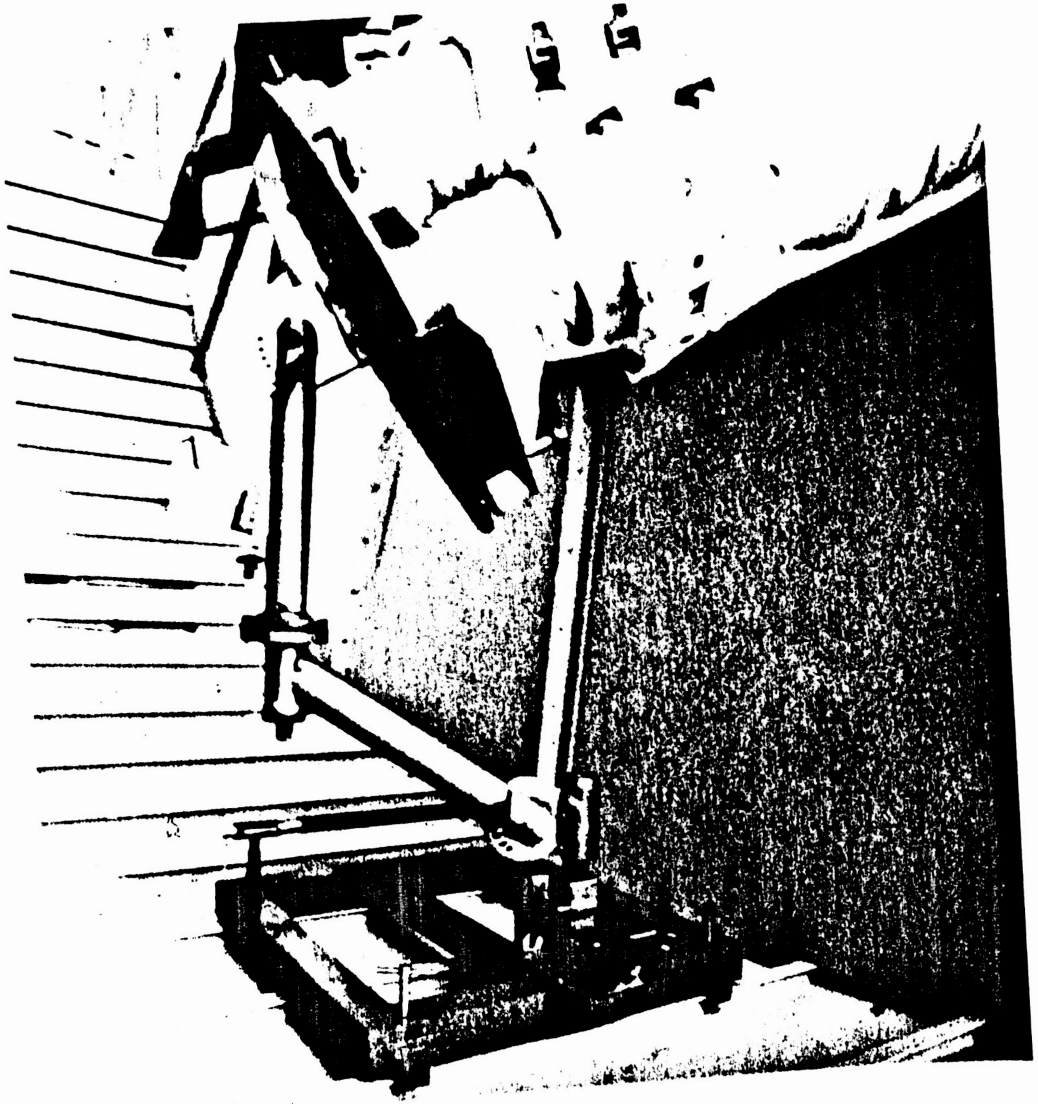


MARTIN MARIETTA
MANNED SPACE SYSTEMS

9

ffb#3

EVA Foot Restraint and Platform



ORIGINAL PAGE IS
OF POOR QUALITY

MARTIN MARIETTA
MANNED SPACE SYSTEMS

EVA "Fireman's Pole" Demonstration

Tools Used

- None

Pretest Modifications to Flight Hardware

- None

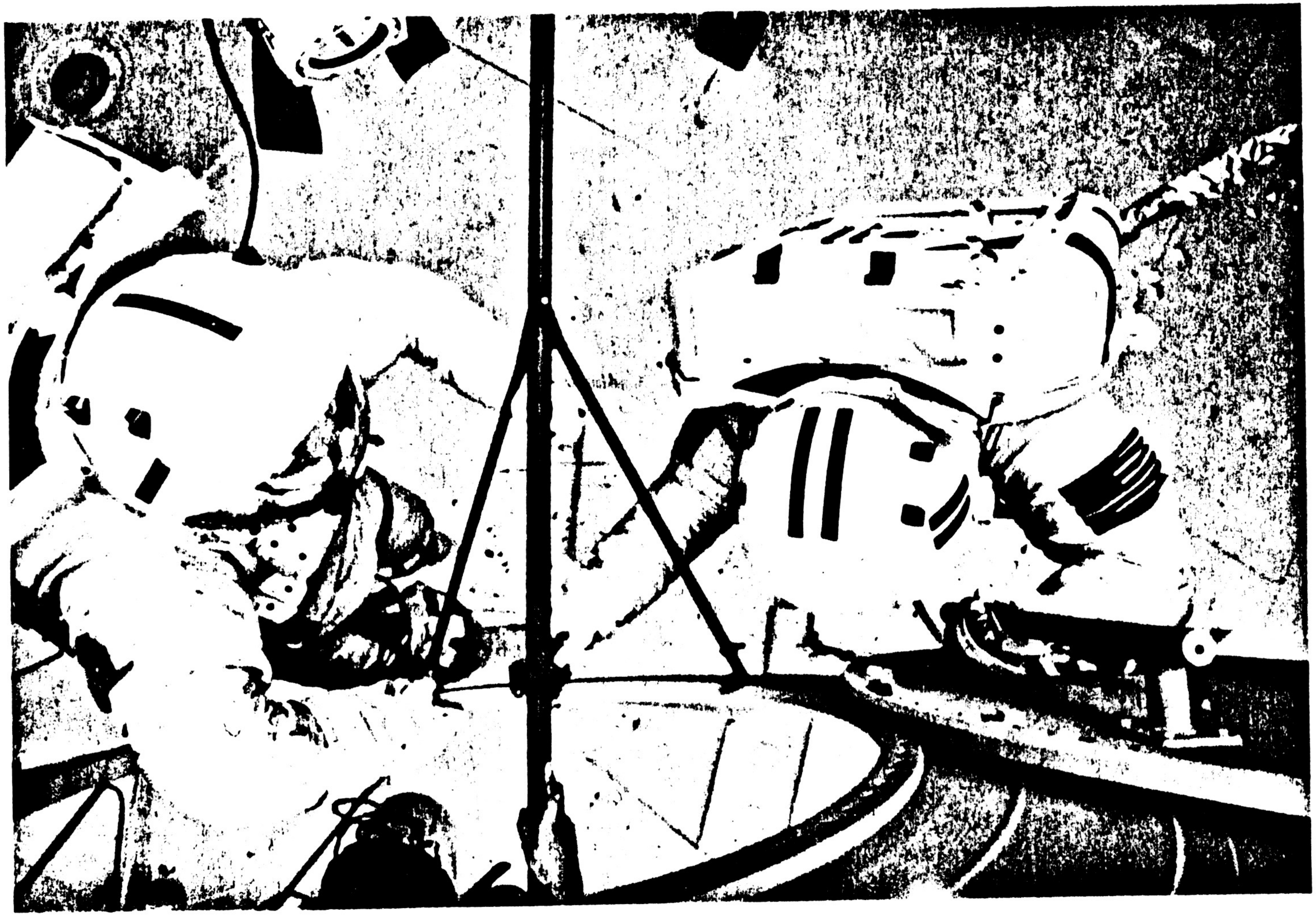
Process

- Insert Angled End of Pole Through Opening
- Align Brackets with the Bolt Hole Pattern Around the Manhole
- Insert Pins and Secure
- Test Subject Entered LH2 Tank Using the Pole - Preferred Head First Entry

Recommendations

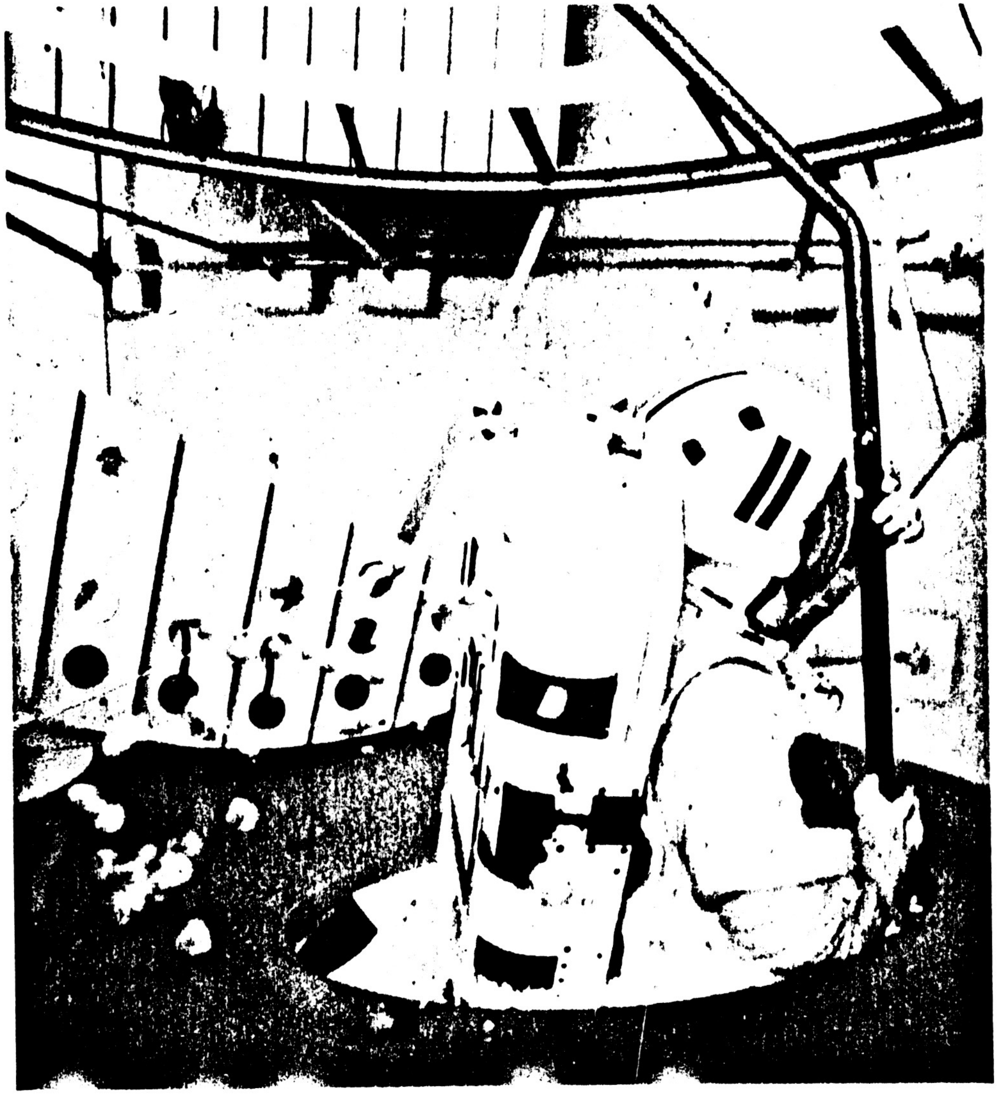
- Modify Tool to Allow Rotation of the Pole After Attachment
- Modify Tool Clamp for Easier Installation
- Increase Length of the Pole From the Top to the Angle
- Increase Standoff Distance from the Clamp

Installation of EVA "Fireman's Pole"



ffb#3

Ingress to LH2 Tank



ORIGINAL PAGE IS
OF POOR QUALITY

MARTIN MARIETTA
MANNED SPACE SYSTEMS

12

ET-GRIT Mirror Installation Demonstration

- Tools Used
  - None

- Pretest Modifications to Flight Hardware
  - None

- Process
  - Installed Brackets Along the Ring Frame to Simulate the Full Circumference of the LH2 Tank
  - Rolled and Secured Inflatable Mirror to Transport Through Manhole
  - Taken to Ring Frame and Unrolled for Installation
  - Installed the Mirror Starting at the 12:00 Position Attaching the Turn Buckles to the Ring Frame Brackets

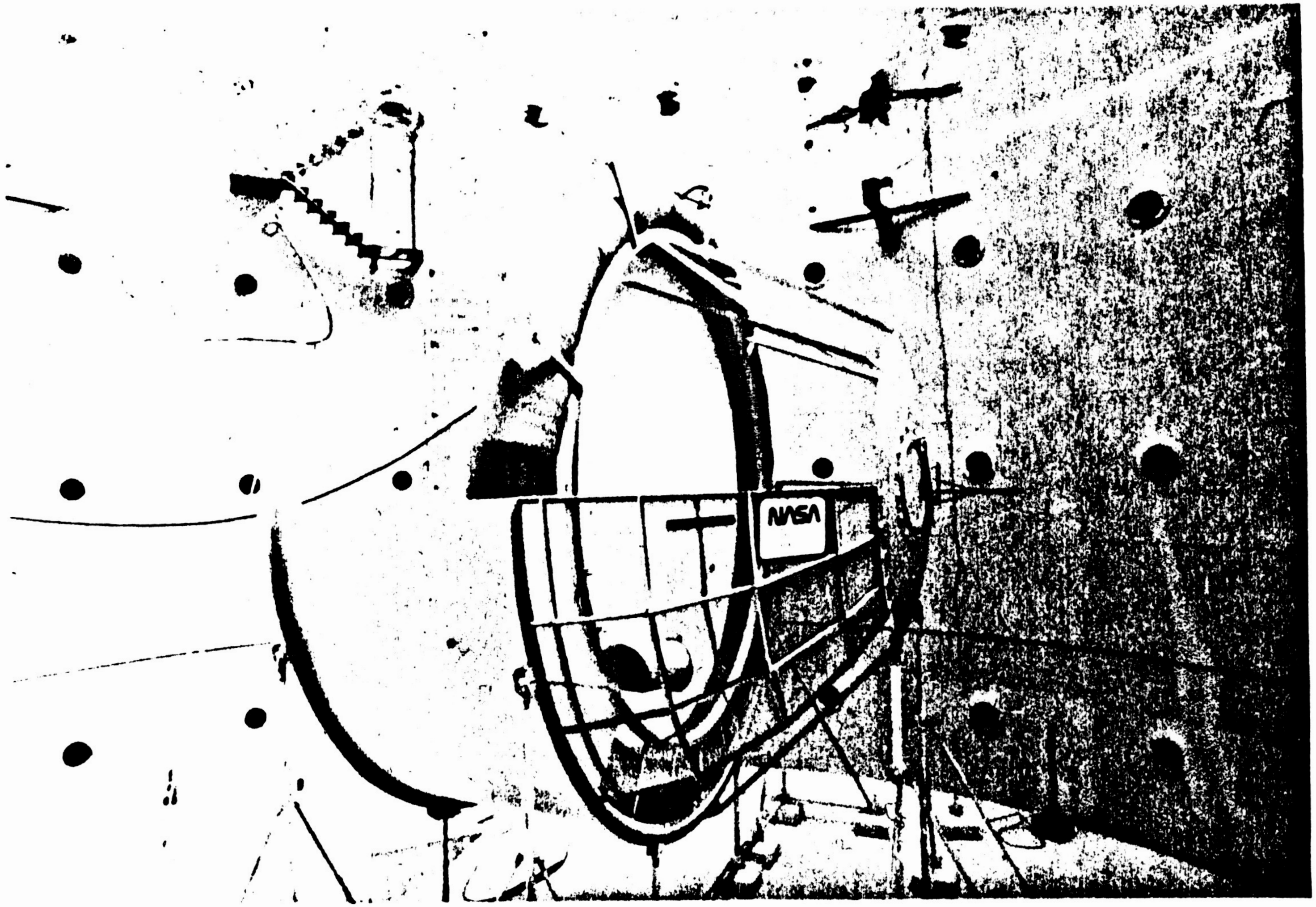
- Recommendations
  - Attach Mirror to LH2 Tank Walls Using the T-stiffeners
  - Add Hand Loops to the Rim of the Mirror
  - Add a Removeable Layer of Material Over the Mirror Surface

Installation of Inflatable Mirror

MARTIN MARIETTA
MANNED SPACE SYSTEMS

ffb#3

Inflated Simulated Mirror



MARTIN MARIETTA
MANNED SPACE SYSTEMS

TPS Onorbit Removal Demonstration

C-2

Tools Used

- Pull Handle

Pretest Modifications to Flight Hardware

- None

Process

- Attached Pull Handle to Wire Loop
- Pull Using Outward Motion Along Path Marked on the TPS
- Clip Wire When the End of the Wire is Encountered
- TPS Will Disengage From the Phenolic Ring
- Remove Phenolic Ring from Manhole Cover Bolts

Recommendations

- Replace Pull Handle "Hook" With a Ball
- Remove Cover of the Pull Handle - Use Only Side Guards
- Use Segmented Covers Over Each Hand Rail

Onorbit TPS Removal from Manhole Cover

15

MARTIN MARIETTA
MANNED SPACE SYSTEMS

ffb#3

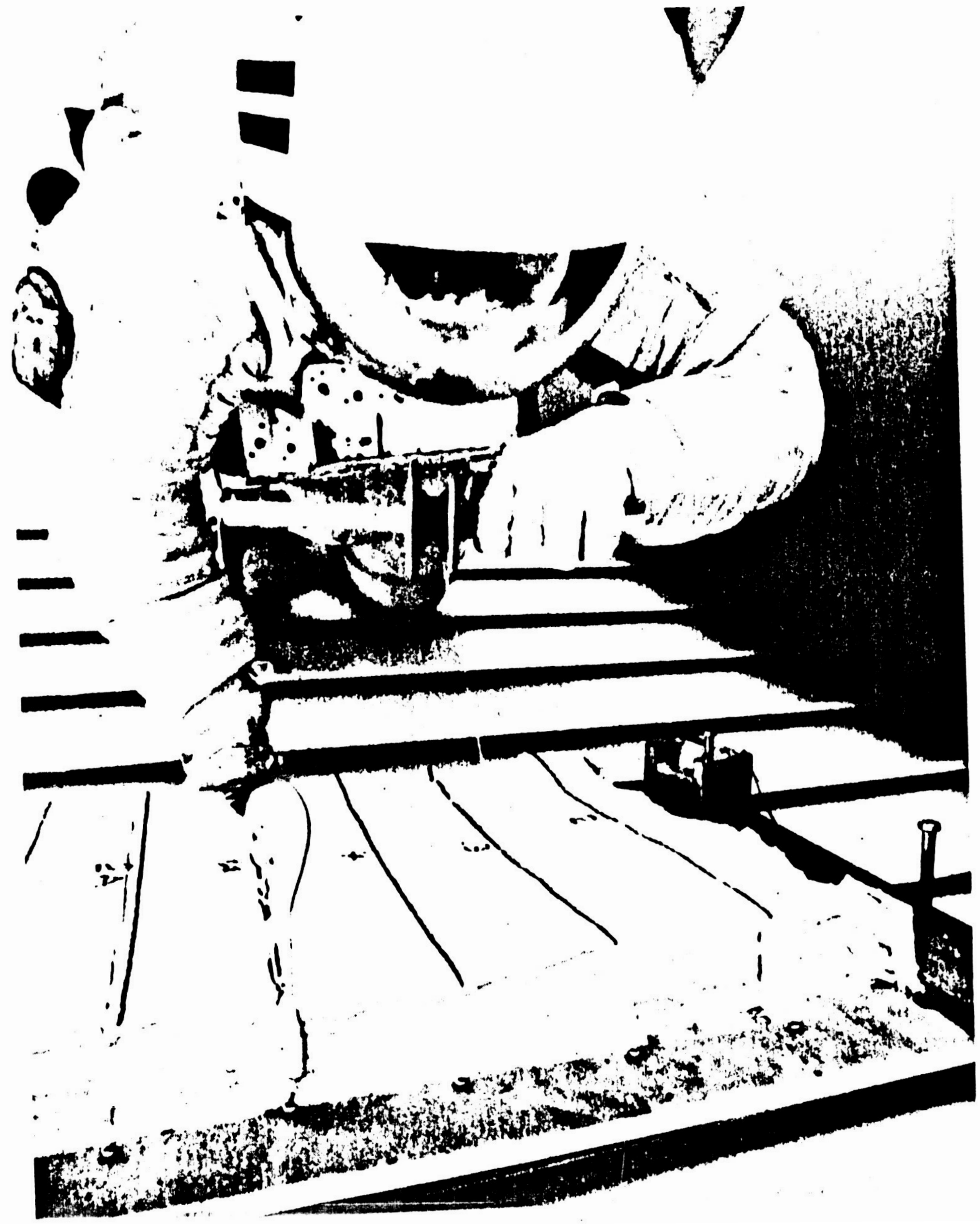
TPS Cutting Wire Demonstration

Identifier	Wire Material	Results
1 1A	Braided Cable - .0625 Diameter	Chunks of Debris
2 2A	Non-Electrical Stainless Steel - .015 Diameter	Little Debris
3 3A	Double Strand Non-Electrical Stainless Steel - 0.15 Diameter	Curled TPS Debris
4 4A	25 Pound Fishing Line	No Debris - Clean Cut Sensitive to Heat

<u>Recommendation</u>

- Use Teflon Coated Non-Electrical Stainless Steel Wire

TPS Cutting Wire Tested



16

ffb#3

MARTIN MARIETTA
MANNED SPACE SYSTEMS

LH2 Tank Manhole Cover Pivot Demonstration

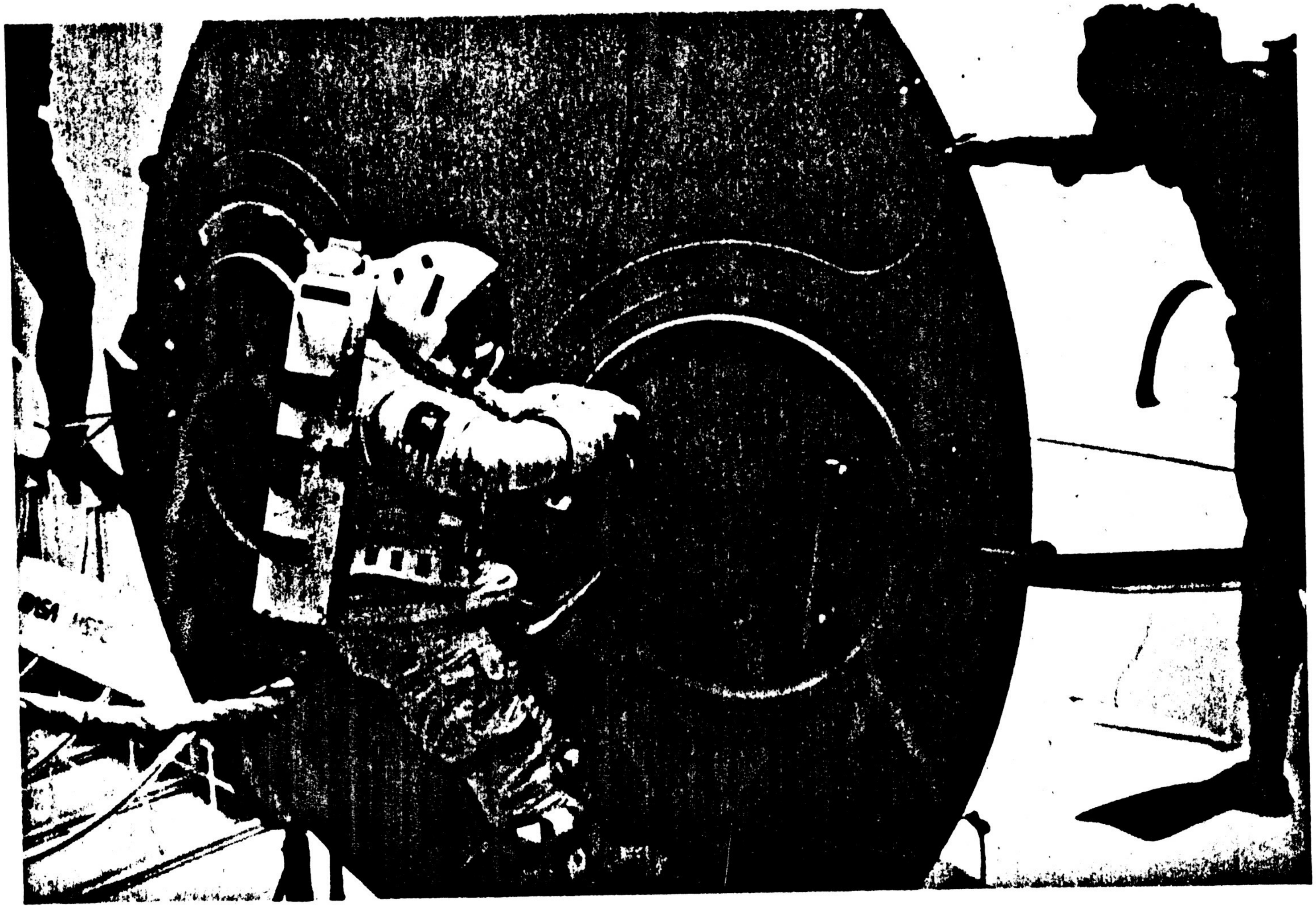
Tools Used
- Pneumatic Air Impact Wrench - 3/8 inch Drive
- Essex Hand Wrench

Pretest Modifications to Flight Hardware
- Two External Hand Rails Mounted to Manhole Cover

Process
- Remove 91 Bolts with Air Impact Wrench
- Loosen Last Bolt 7 Full Turns with Hand Wrench
- Pivot Manhole Cover
- Secure Open with Two 3/8 inch - 12 Point Bolts

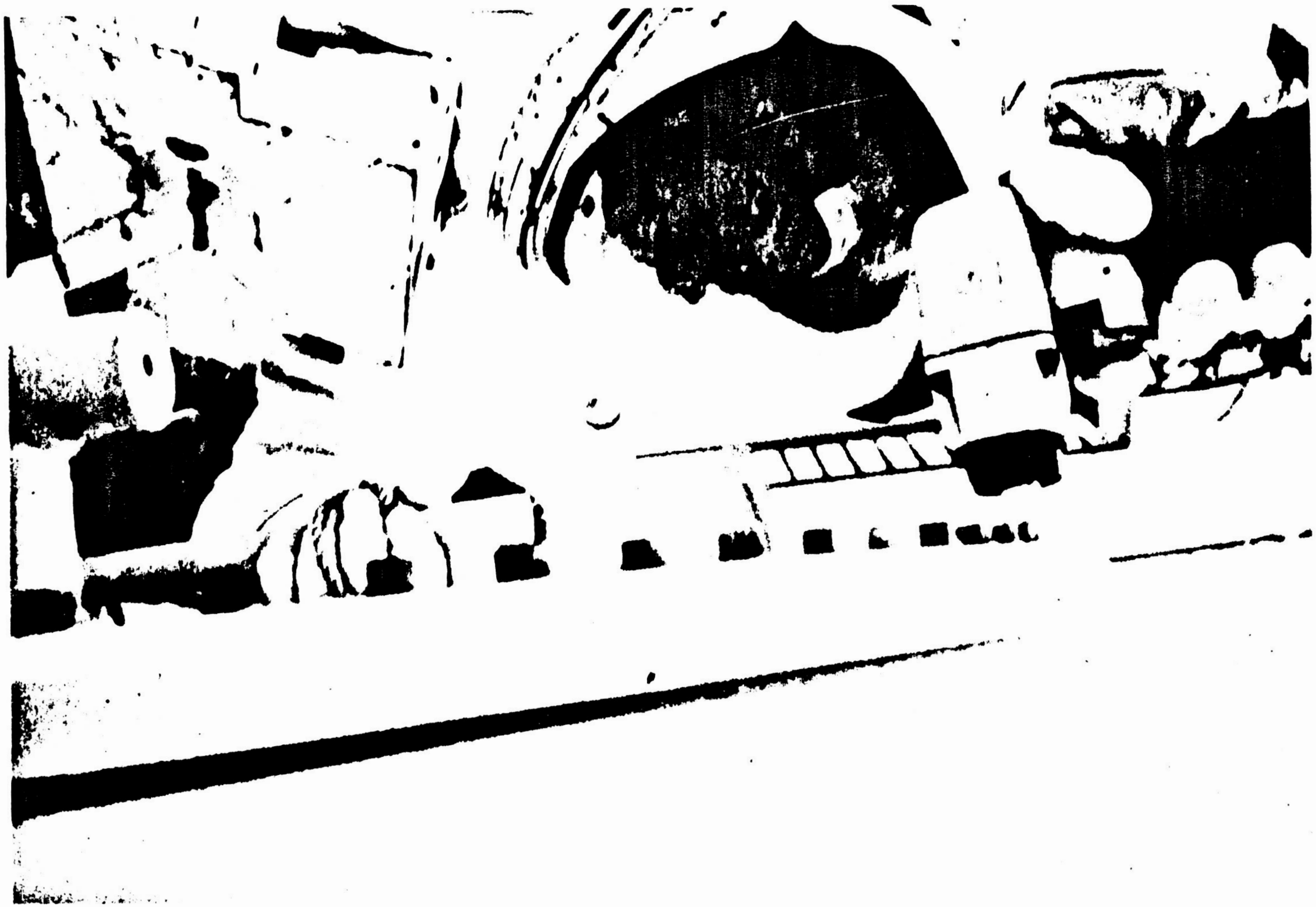
Recommendations
- Replace Manhole Cover Bolts with Captured Bolts
  - Reduces EVA Time
  - Reduces Potential Space Debris

LH2 Aft Manhole Cover



MARTIN MARIETTA
MANNED SPACE SYSTEMS

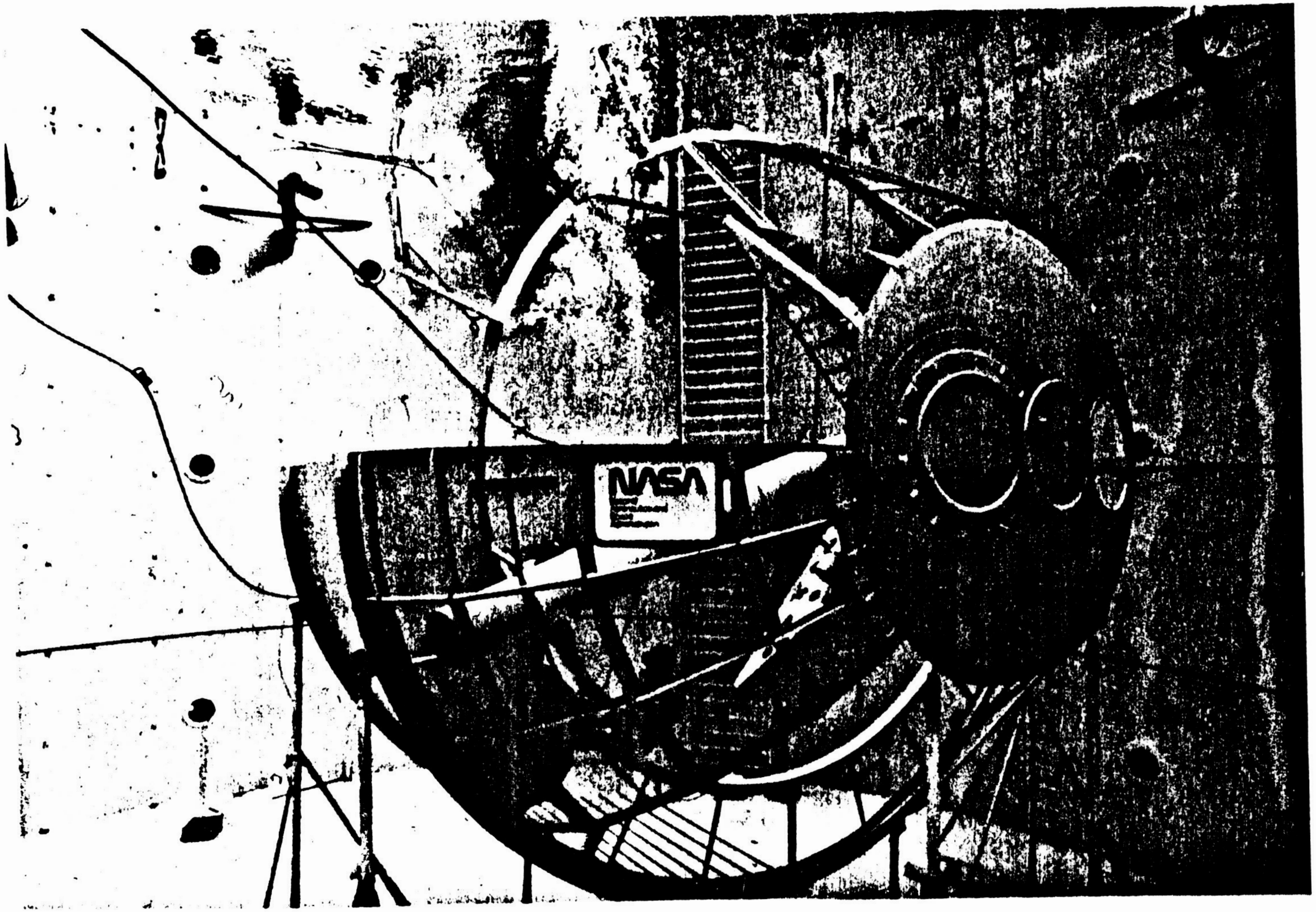
LH2 Manhole Bolt Removal



15

MARTIN MARIETTA
MANNED SPACE SYSTEMS

Pivoted LH2 Aft Manhole Cover



MARTIN MARIETTA
MANNED SPACE SYSTEMS

Mission Operations Concepts

ET-GRIT Conversion/Assembly Mission Scenarios

Mission One (ET Conversion)

	1 Hr	- Gain Access to ET Interior (LH2/Intertank)
EVA 1	1 Hr	- Mount Rig LH2/Intertank Lighting/Comm
	3 to 4 Hrs	- Mount Subsystems Boxes (Intertank Area)
EVA 2		
	2 Hrs	- Mount OMV Interface Plate (Nose Area)
		- OMV Docks
		- Check Out

Mission Two (GRIT Assembly)

	2 to 3 Hrs	- Remove LH2 Siphon and Stow
EVA 1		
	2 to 3 Hrs	- Mount Telescope Detectors, Scintillators, Boxes
EVA 2	2 Hrs	- Mount/Adjust Inflatable Mirror Surface
	1 Hr	- Seal Tank/Pressurize
		- Check Out and Begin Operation

1-5769-7-11T

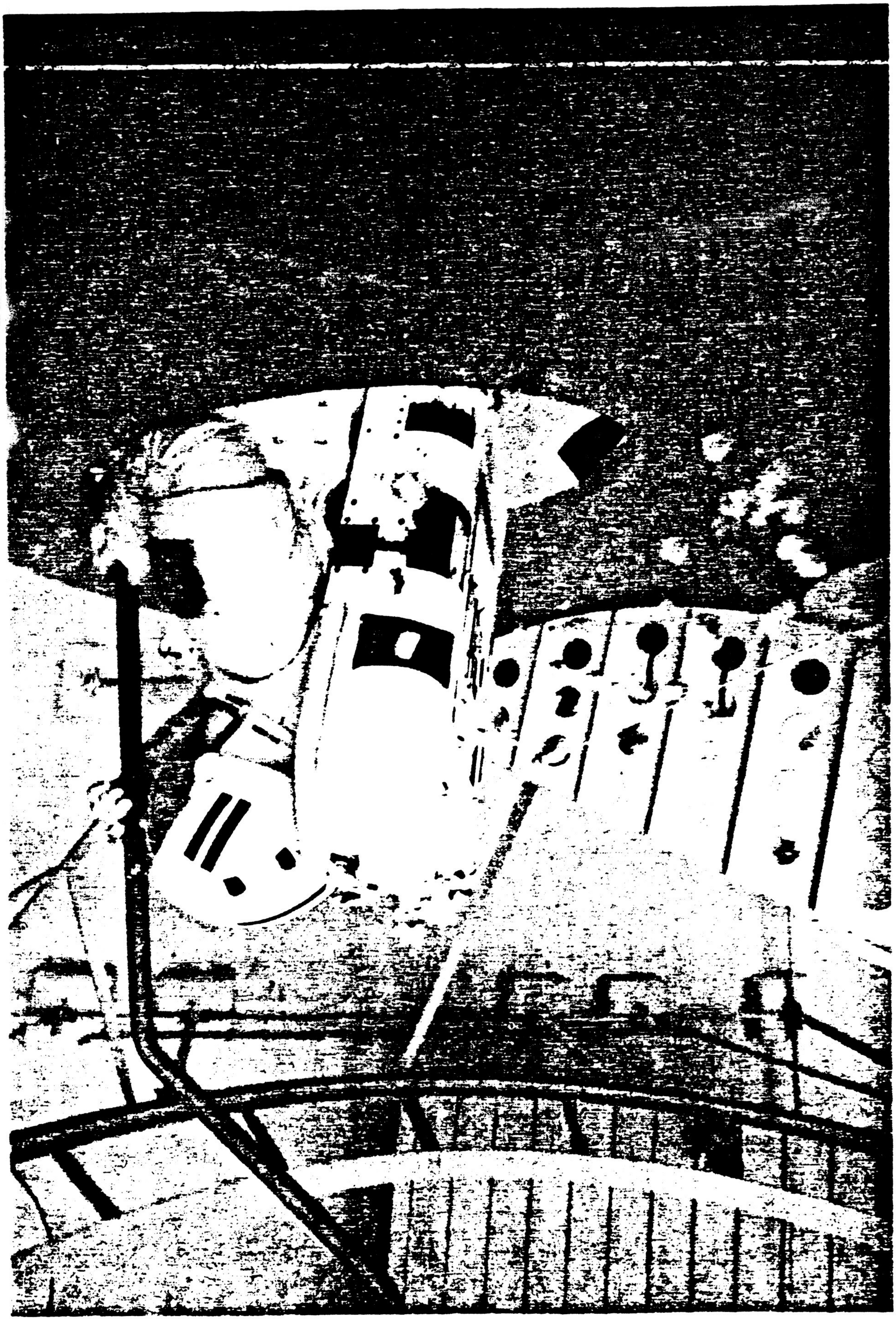
ET-GRIT EVA ASSUMPTIONS/GROUND RULES

- ALL EVA TASK TIMES ARE ESTIMATES BASED ON NBS TESTS OR PRIOR STS MISSIONS
- DESIGN GOAL FOR MAXIMUM OF 3 PLANNED EVA'S FOR ET-GRIT MISSION
- NO EVA WILL EXCEED 6 TASK HRS. (I.e., 12 MHRS)

ORIGINAL PAGE IS
OF POOR QUALITY

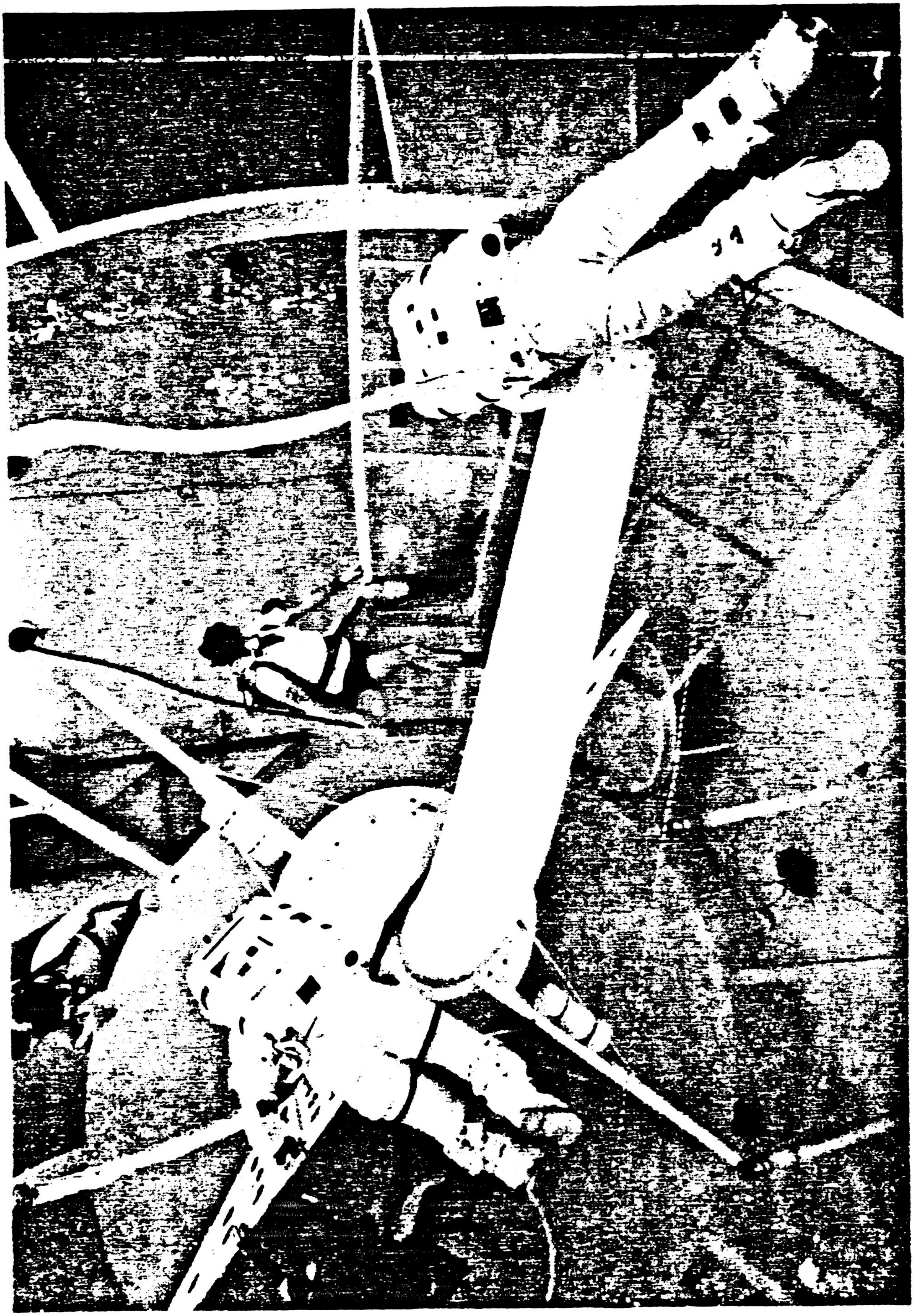
TPS REMOVAL METHODOLOGY

- REMAINING TPS MAY STILL BE COVERING SOME BOLTS/HANDHOLDS/ATTACH POINTS AND, WOULD HAVE TO BE REMOVED ON ORBIT
- SPACE DEBRIS OF ALL SORTS MUST BE MINIMIZED, INCLUDING TPS RESIDUE
- PULL WIRE TECHNIQUE (WIRE BURIED IN TPS PRIOR TO LAUNCH) REMOVES TPS CLEANLY, USING PIANO TYPE WIRE; QUICK CUTTING, VIRTUALLY NO DEBRIS
- WIRE PULLING/ROLLING TOOL (PHASE 1 CONCEPT) WORKS VERY WELL
- MULTIPLE, SINGLE STRAND, WIRES SHOULD BE BURIED TO PROVIDE CONTINGENCY PULL WIRE, SHOULD PRIMARY PULL WIRE FAIL
- WIRE CAN CUT TPS AT APPROX. 2 FEET/MINUTE (DEMONSTRATED)



ET INGRESS/EGRESS METHODOLOGY

- PRIMARY POINT OF ET ENTRANCE WILL BE THE LH_2 TANK AFT DOME MANHOLE COVER, AS DEMONSTRATED DURING PHASE 1
- TPS REMOVAL SHOULD CLEAR ALL BOLTS AND HANDHOLDS IN APPROX. 10 MINUTES (REMOVAL TECHNIQUES DEMONSTRATED)
- BOLTS MUST BE CAPTURED; FLIGHT TORQUES ALLOW FOR USE OF THE EVA POWER TOOL, AT APPROX. 8 BOLTS/MINUTE (91 BOLTS)
- MANHOLE COVER WILL BE PIVOTED ON FINAL BOLT; THE PIVOT MANEUVAR PRECLUDES COVER REMOVAL/TETHER/REALIGNMENT
- FINAL STEP IS TO MOUNT THE "FIREMAN'S POLE" THUS PROVIDING A HANDHOLD, INTERIOR LIGHTING/COMM; APPROX. 10 MINUTE TASK
- OVERALL LH_2 TANK INGRESS TIME: 30 MINUTES (ESTIMATED)



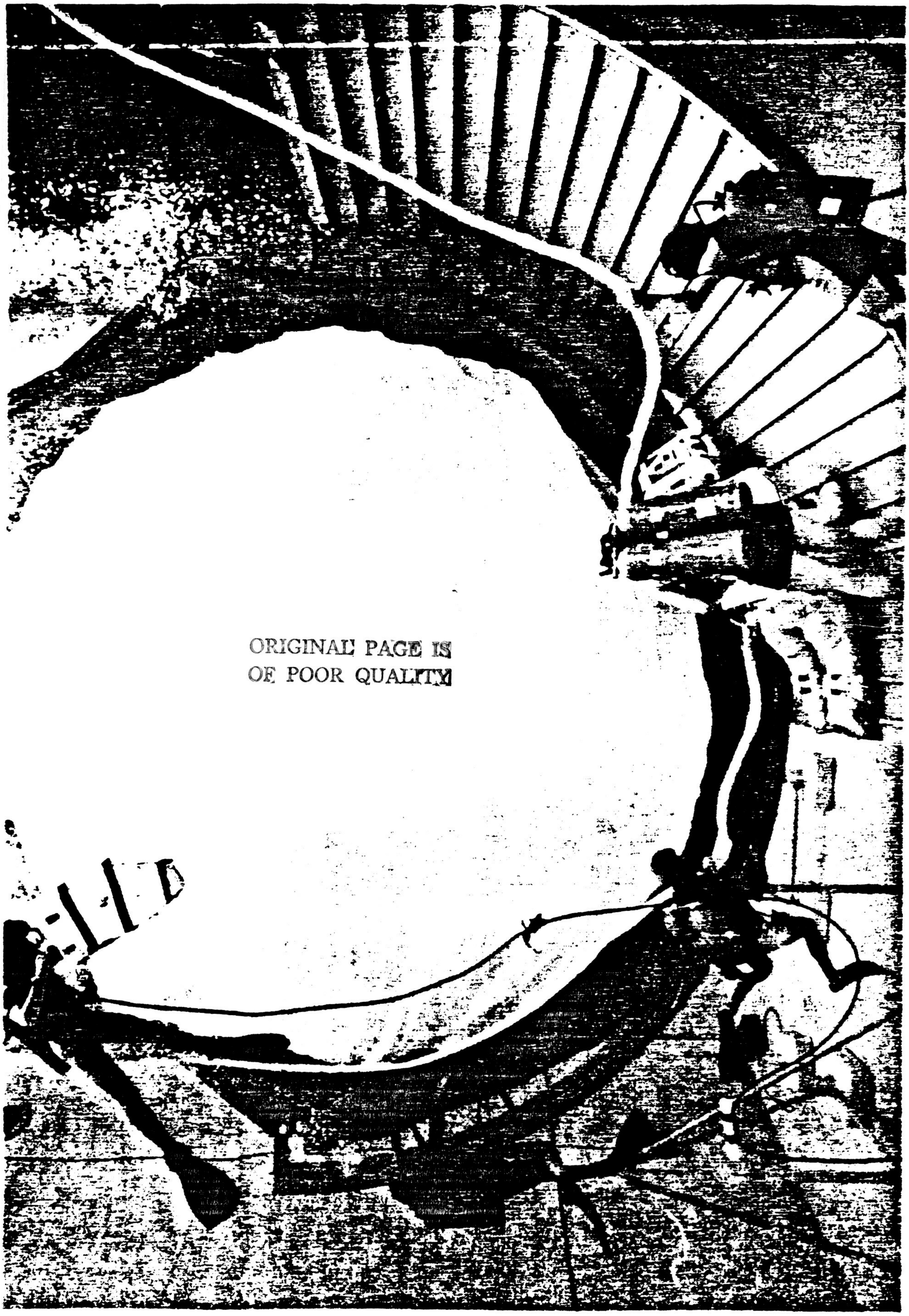
ORIGINAL PAGE IS
OF POOR QUALITY

22

1-6751-7-13T

LH_2 SIPHON REMOVAL PROOF OF CONCEPT

- THE FLIGHT CONFIGURATION LH_2 SIPHON IS REMOVABLE BY TWO EMU SUITED ASTRONAUTS
- BELLOWS TO SIPHON INTERFACE (52 BOLTS AT 700 IN/LBS.) REPRESENTS THE "TALL POLE"; OTHER ASPECTS OF THE TASK ARE STRAIGHT FORWARD
- BELLOWS TO SIPHON BOLTS/NUTS SHOULD BE CAPTURED, WITH SUFFICIENT HEAD AREA TO PROVIDE SECURE WRENCH MATING
- FOOT RESTRAINTS AND TETHERS ARE REQUIRED; T-STRINGER FOOT RESTRAINT BRACKET IS AN EXCELLENT, RIGID PORTABLE FOOT RESTRAINT MOUNT
- TRANSLATION OF SIPHON ASSEMBLY TO FORWARD END OF LH_2 TANK, REQUIRES TRANSLATION LINE AND MINIMUM IMPARTED MOMENTUM TO SIPHON ASSY.
- REMOVAL AND TRANSLATION TIME: 1 HOUR (ESTIMATED)



1-6752-7-13T

INFLATABLE MIRROR ATTACHMENT PROOF OF CONCEPT

- INFLATABLE MIRROR WAS ROLLED UP AND PASSED THROUGH THE 36" MANHOLE EASILY
- MIRROR ATTACHMENT WAS TO THE RING FRAME, BUT T-STRINGER ATTACHMENT APPEARS TO BE THE DESIRABLE OPTION (NO BOLTS, NO HOLES)
- MIRROR DEPLOYMENT WAS INITIATED AFTER ONE ATTACHMENT POINT HAD BEEN SECURED, THUS PROVIDING STABILITY FOR THE UNFURLING
- CIRCULAR ATTACHMENT APPROACH ALLOWED CREW TO WORK INDEPENDENT OF EACH OTHER AND PROVIDED PROMPT COMPLETION OF THE TASK
- T-STRINGER ATTACHMENT MECHANISMS ARE ALREADY DESIGNED; TURNBUCKLES WOULD PROVIDE MIRROR TENSION/ADJUSTMENT IF NEEDED
- MIRROR INSTALLATION TIME (T-STRINGER ATTACHMENT): 1 HOUR (ESTIMATED)

ORIGINAL PAGE IS
OF POOR QUALITY

1-6753-7-13T

ET-GRIT PHASE 2 NBS TEST SERIES SUMMARY

- ALL MAJOR OBJECTIVES WERE MET/ACCOMPLISHED
- ALL CONCEPTS, BOTH HARDWARE/TECHNIQUE, PROVED FEASIBLE
- OPTIMIZATION OF HARDWARE/PROCEDURES WILL BE STRAIGHT FORWARD IN MOST CASES
- PHASE 1 DETERMINATIONS WERE INCORPORATED DIRECTLY INTO PHASE 2 PROCEDURES AND PROVED SUCCESSFUL
- CREW REQUIREMENTS FOR ET-GRIT CONVERSION ARE REASONABLE
- THE ET-GRIT CONVERSION APPEARS TO REQUIRE TWO STS EVA MISSIONS, POSSIBLY LESS

ET-GRIT PHASE 3 NBS TEST PROPOSAL

- ACQUIRE/BUILD ET INTERTANK MOCKUP
- FABRICATE ET T–STRINGER ATTACH POINTS FOR MIRROR AND DEMONSTRATE
- INVESTIGATE SUBSYSTEM ATTACHMENT TECHNIQUES WITH REPRESENTATIVE BOXES/DEVICES/PAYLOAD MOCKUPS
- CHARACTERIZE INTERTANK EVA INGRESS/EGRESS AND WORK ENVELOPE, TO FURTHER DETERMINE ON ORBIT ACCESS/TIMELINES
- DESIGN/BUILD/INSTALL OMV TARGET/DOCK POINT MOCKUP FOR ET NOSE CONE

ET-GRIT CONVERSION/ASSEMBLY MISSION SCENARIOS

MISSION ONE (ET CONVERSION)

- GAIN ACCESS TO ET INTERIOR (LH_2 /INTERTANK)
- MOUNT RIG LH_2 /INTERTANK LIGHTING/COMM
- MOUNT SUBSYSTEMS BOXES (INTERTANK AREA)
- MOUNT OMV INTERFACE PLATE (NOSE AREA)
- OMV DOCKS
- C/O AND RELEASE FROM STS

MISSION TWO (GRIT ASSEMBLY)

- REMOVE LH_2 SIPHON AND STOW
- MOUNT TELESCOPE DETECTORS, SCINTILLATORS, BOXES
- MOUNT/ADJUST INFLATABLE MIRROR SURFACE
- SEAL TANK/PRESSURIZE
- C/O AND BEGIN OPERATION

ET-GRIT OPERATIONAL/ASSEMBLY CONCLUSIONS

- ET CAN BE CONVERTED INTO A SPACECRAFT IN ONE DEDICATED STS MISSION (CARGO SPACE AVAILABLE FOR OTHER PAYLOADS)

- THE ET SPACECRAFT CAN THEN BE FURTHER CONVERTED INTO GRIT IN ONE MORE DEDICATED STS MISSION

- FURTHER OPERATIONAL STUDY REQUIRED FOR METEOROID SHIELD DESIGN AND INSTALLATION (HOW TO INSTALL/WHEN TO INSTALL)

- FURTHER OPERATIONAL STUDY REQUIRED FOR SUBSYSTEMS MOUNTING ON INTERIOR/EXTERIOR OF INTERTANK (PRELAUNCH/EVA/ROBOTICS)

Thermal Control

ET-GRIT THERMAL REQUIREMENTS AND ASSUMPTIONS

● REQUIREMENTS

H_2 TANK

- Maintain gas (CO_2) temperature between -10° and 40°C (14° to 104 °F) with no more than a 15 °C (27°F) gradient across tank interior
- Reject 1 kW of power from science instruments

INTER-TANK : AVIONICS EQUIPMENT

- Maintain avionics subsystem electronics below 40 °C (104 °F)
- Reject 1242 W during sun portion and 903 W during shadow portion of orbit

● ASSUMPTIONS

- ET Exterior surface: absorptivity = $\alpha = 0.8$, emissivity = $\varepsilon = 0.8$
- 270 NMi ; 28.5° ; Sun oriented orbit
- 0.75 in. exterior SOFI thickness
- 0.2 in. Aluminum wall thickness
- Aft end heating contributions are neglected
- Fluid is CO_2 @ 2.6 psia

ET- GRIT THERMAL CONTROL OPTIONS

- **H_2 TANK**
  - Forced convection
  - Selective Surface Coatings
  - Meteoroid / debris shield
  - MLI

- **INTER-TANK / AVIONICS EQUIPMENT**
  - Selective exterior surface coating
  - Power modules radiate to cold wall
  - Power modules conduct to cold wall *

*** Not included in analysis**

LH2 Tank Thermal Control Requirements

- Bulk Temperature Range

- Maximum Allowable Temperature Gradient in Pressurization Gas Raised to 15º C (24º F) From 5º C (8º F)

- PMT Allowable Temperature Range
  - Non-Operating ~ -196º C to 85º C (-282º F to 168º F)
  - Operating ~ -10º C to 40º C (16º F to 96º F)
  - Ideal Temperature ~ 22º C (67º F)
    - Power Consumption
    - Sensitivity

- Electronics Temperature Range
  - Non-Operative
  - Operative

Orbital Heating

- Bumper Was Not Baselined in Previous Study
  - MLI May Be Integrated to Bumper
    - -- No Additional EVA
    - -- Bumper ~ 10% Heavier
    - -- Simplify Isothermality
    - -- Longer Transients for Hot/Cold Pointing Angles
  - Surface Coatings May Be Applied to Bumper to Set Mean Orbital Temperature as Required by Components
- Previous Study Indicated Possible Temperatur Problems at Pointing Extremes
- Initiated Thermal Assessment for a "Real Case" Pointing Schedule
  - Performed TRASYS Orbital Heating Analysis
    - Used Six Celestial Targets from Momentum Management Analysis
  - MITAS Analysis Pending

ET-GRIT Average Orbital Heating

- 6 Selected Celestial Targets and Boundary Cases

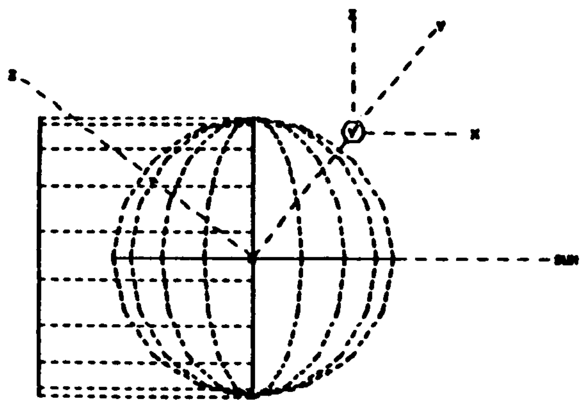
Targets	Avg $\dot{Q}$ (BTU/FT^2 - Hr)
1	97.88
2	98.93
3	84.27
4	97.59
5	79.62
6	88.10
Cold Oriented	27.44
Hot Oriented	102.64

LH2 Tank Barrel Area ~ 16 sections x 450 Sq. Ft.

ET-GRIT ORBIT DEFINITION

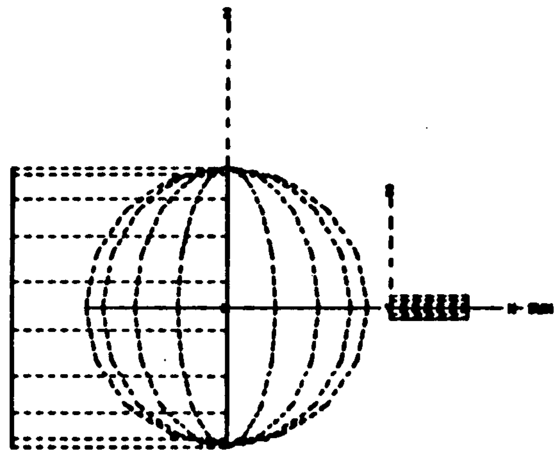
270 NMI, 28.5 ° inclination

WORST CASE HOT



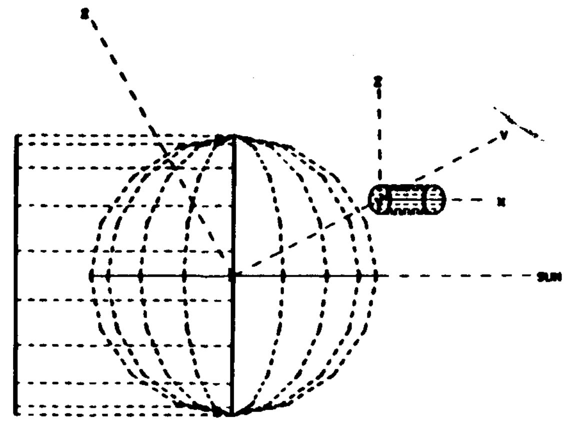
BETA = 52°
⊥ TO SUN VECTOR

WORST CASE COLD



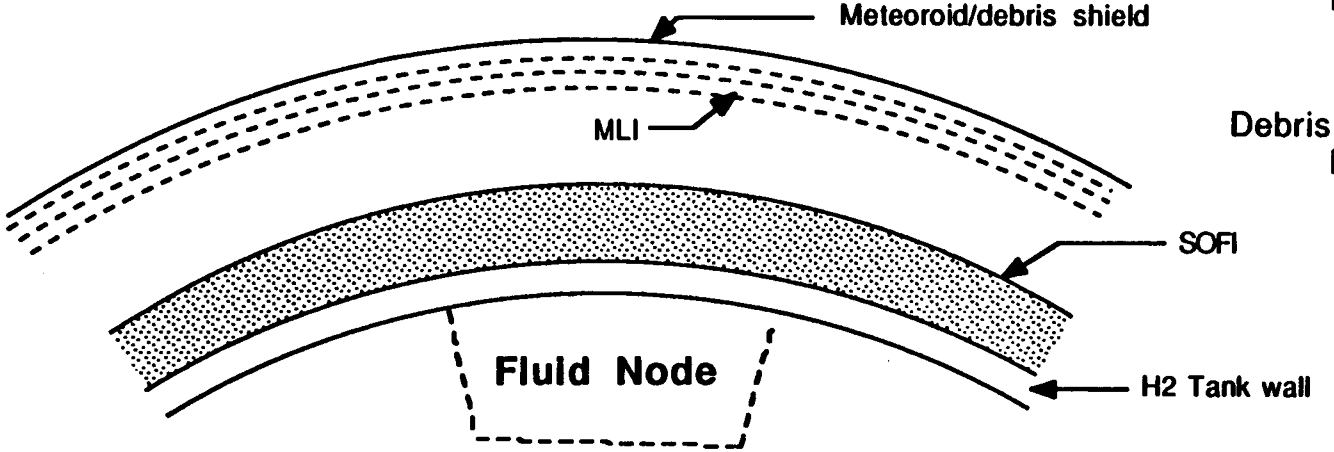
BETA = 0°
II TO SUN VECTOR

NOMINAL



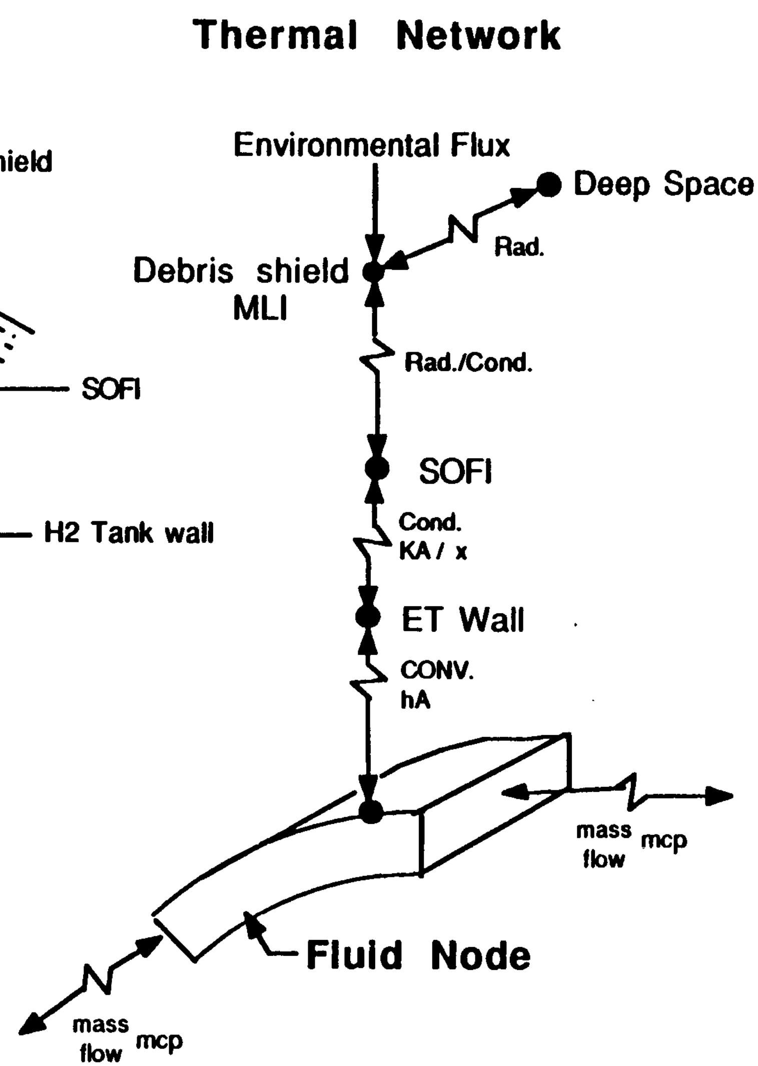
BETA = 28.5°
45 °TO SUN VECTOR

ET-GRIT FLUID NODE SCHEMATIC AND ENERGY BALANCE

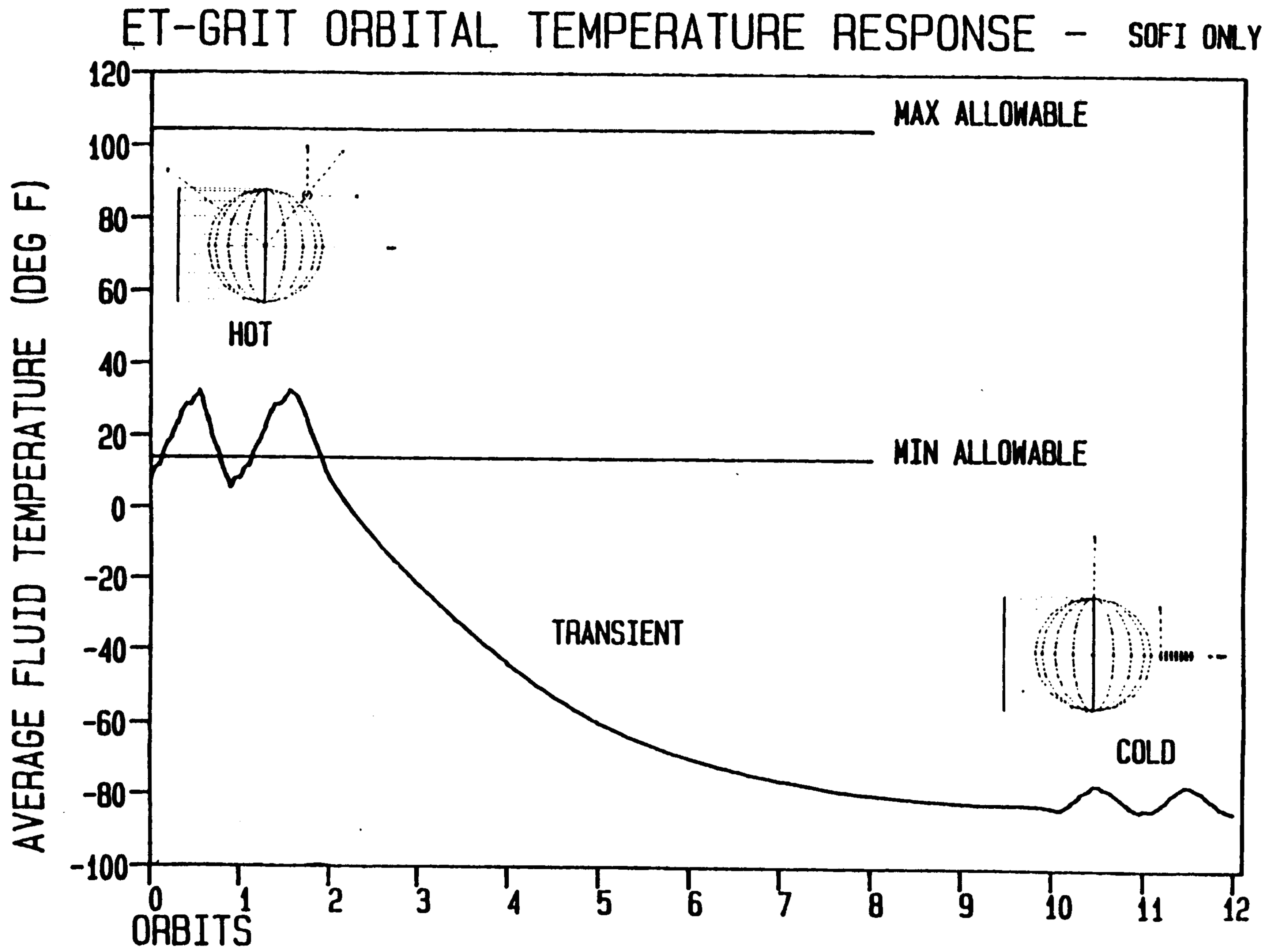


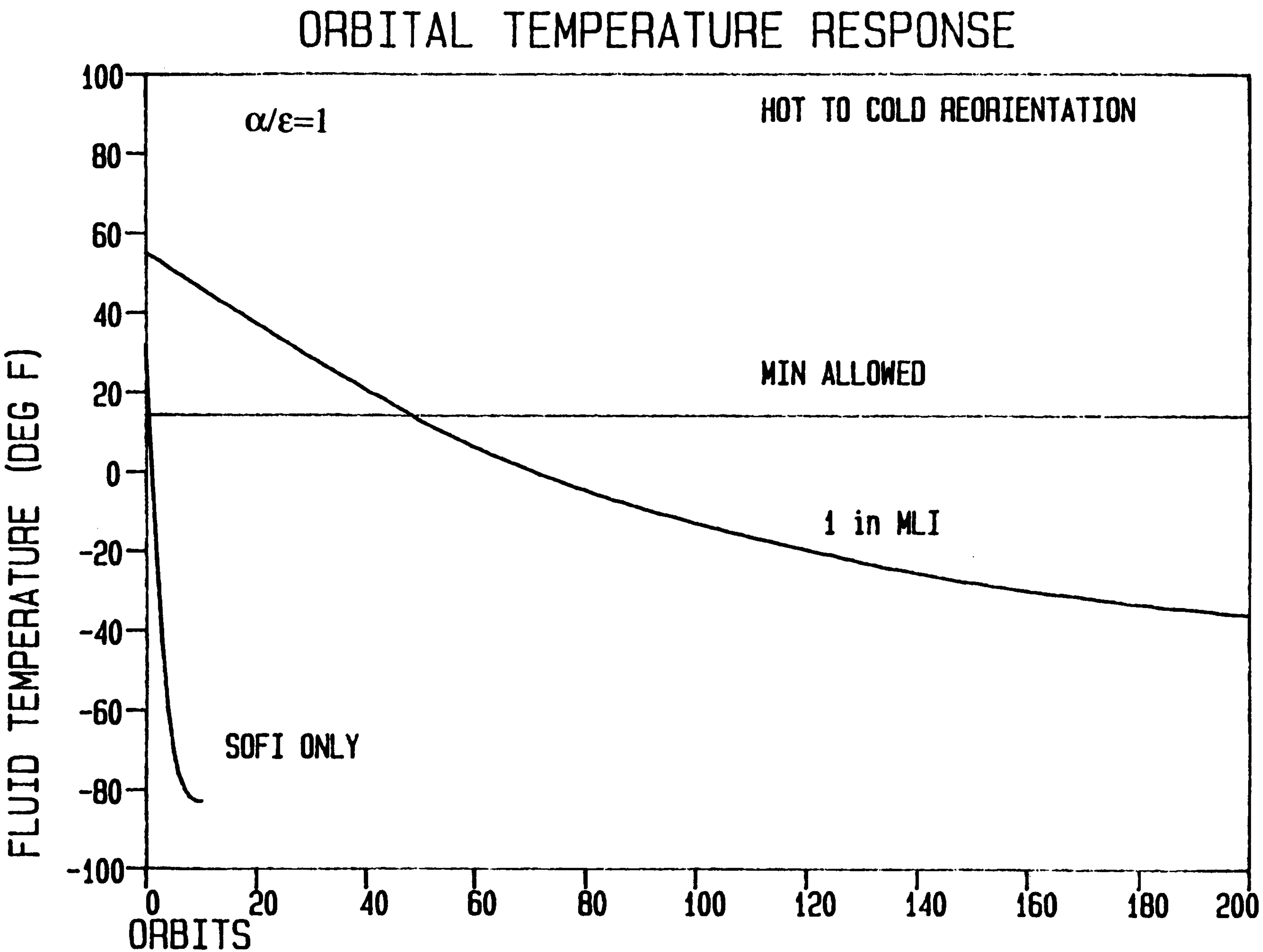
Not To Scale

9 circumferential nodes
1 longitudinal node

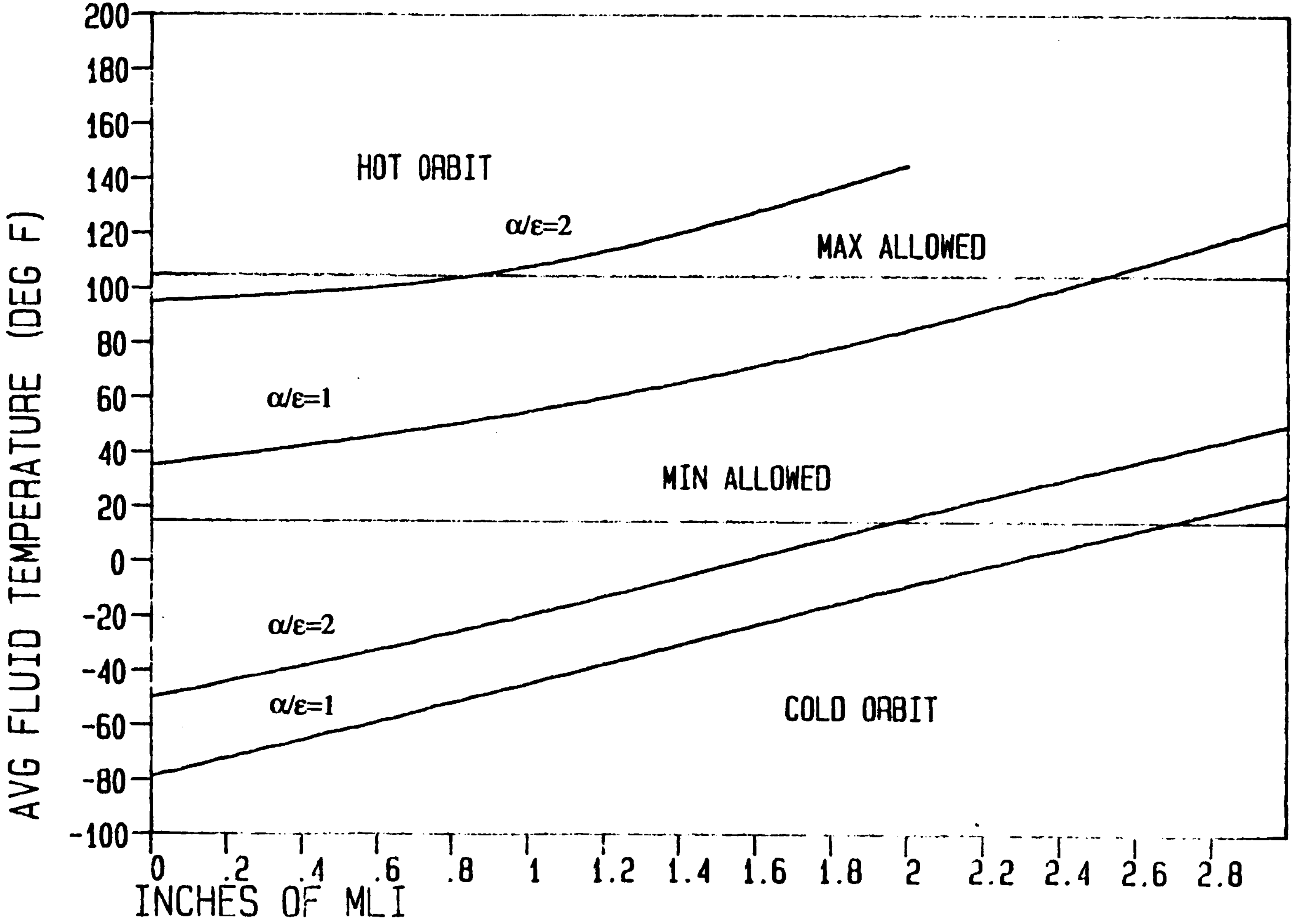


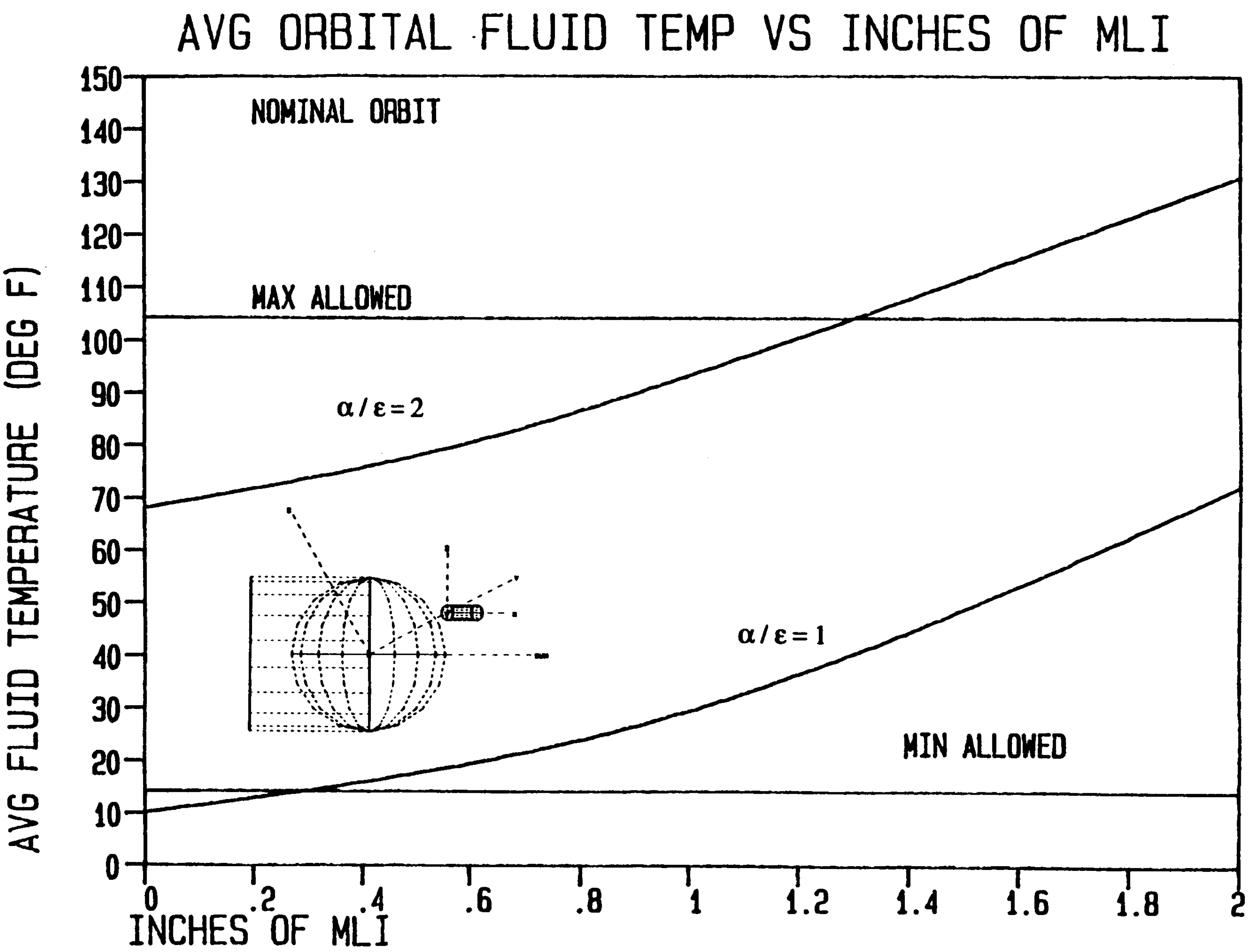
S.P. TUCKER / PD22


ET-GRIT ORBITAL TEMPERATURE RESPONSE - SOFI ONLY
MAX ALLOWABLE
MIN ALLOWABLE
HOT
TRANSIENT
COLD
AVERAGE FLUID TEMPERATURE (DEG F)
ORBITS
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
0
1
2
3
4
5
6
7
8
9
10
11
12

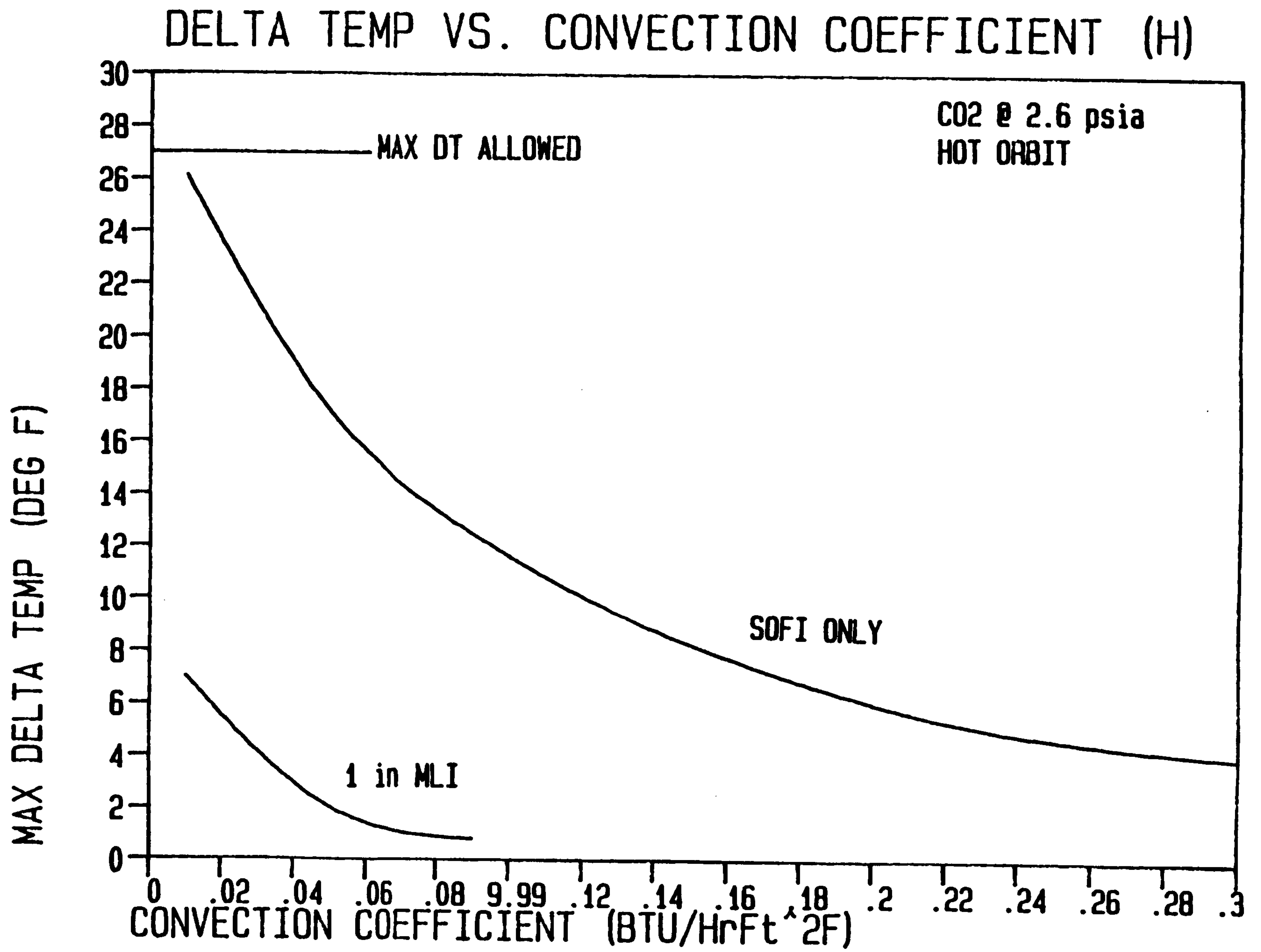

ORBITAL TEMPERATURE RESPONSE
α/ε=1
HOT TO COLD REORIENTATION
MIN ALLOWED
1 in MLI
SOFI ONLY
FLUID TEMPERATURE (DEG F)
ORBITS
100
80
60
40
20
0
-20
-40
-60
-80
-100
0
20
40
60
80
100
120
140
160
180
200

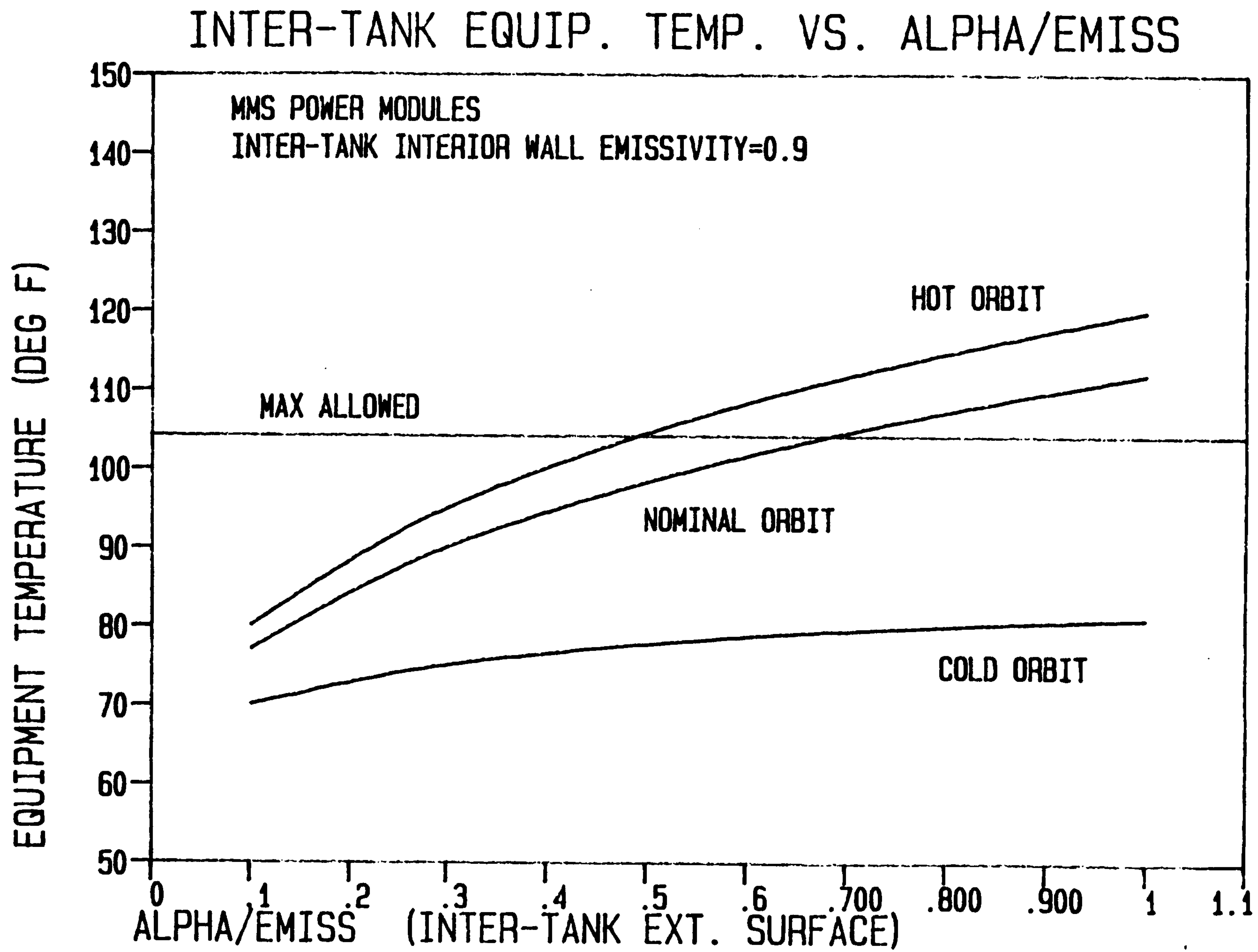
ORBITAL AVG FLUID TEMP VS MLI THICKNESS





AVG ORBITAL FLUID TEMP VS INCHES OF MLI
NOMINAL ORBIT
MAX ALLOWED
MIN ALLOWED
α / ε = 2
α / ε = 1
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
AVG FLUID TEMPERATURE (DEG F)
0
.2
.4
.6
.8
1
1.2
1.4
1.6
1.8
2
INCHES OF MLI


DELTA TEMP VS. CONVECTION COEFFICIENT (H)
MAX DT ALLOWED
CO2 @ 2.6 psia
HOT ORBIT
SOFI ONLY
1 in MLI
MAX DELTA TEMP (DEG F)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
0 .02 .04 .06 .08 9.99 .12 .14 .16 .18 .2 .22 .24 .26 .28 .3
CONVECTION COEFFICIENT (BTU/HrFt^2F)


INTER-TANK EQUIP. TEMP. VS. ALPHA/EMISS
MMS POWER MODULES
INTER-TANK INTERIOR WALL EMISSIVITY=0.9
MAX ALLOWED
HOT ORBIT
NOMINAL ORBIT
COLD ORBIT
EQUIPMENT TEMPERATURE (DEG F)
150
140
130
120
110
100
90
80
70
60
50
0
.1
.2
.3
.4
.5
.6
.700
.800
.900
1
1.1
ALPHA/EMISS (INTER-TANK EXT. SURFACE)

ET-GRIT PHASE II THERMAL ANALYSIS

SUMMARY

- Orbital average bulk gas (CO_2) temperature ranges from 22 to - 80 ° F with no thermal protection system (TPS) other than SOFI
- Gas temperature gradient requirements can be achieved by forced convection
- Mounting avionics subsystem equipment modules inside intertank is no problem (except power modules)
- Mounting electrical power modules inside intertank presents hot case problem with current SOFI properties and radiative cooling
- Extreme pointing orientations may present design problems
- Meteoroid/debris shield provides significant thermal advantage
  - MLI may be intergrated to shield
  - Surface coatings may be applied to shield to improve gas temperatures
  - Longer thermal transients allow limited viewing time at hot/cold pointing extremes

S. TUCKER / PD22

Programmatics

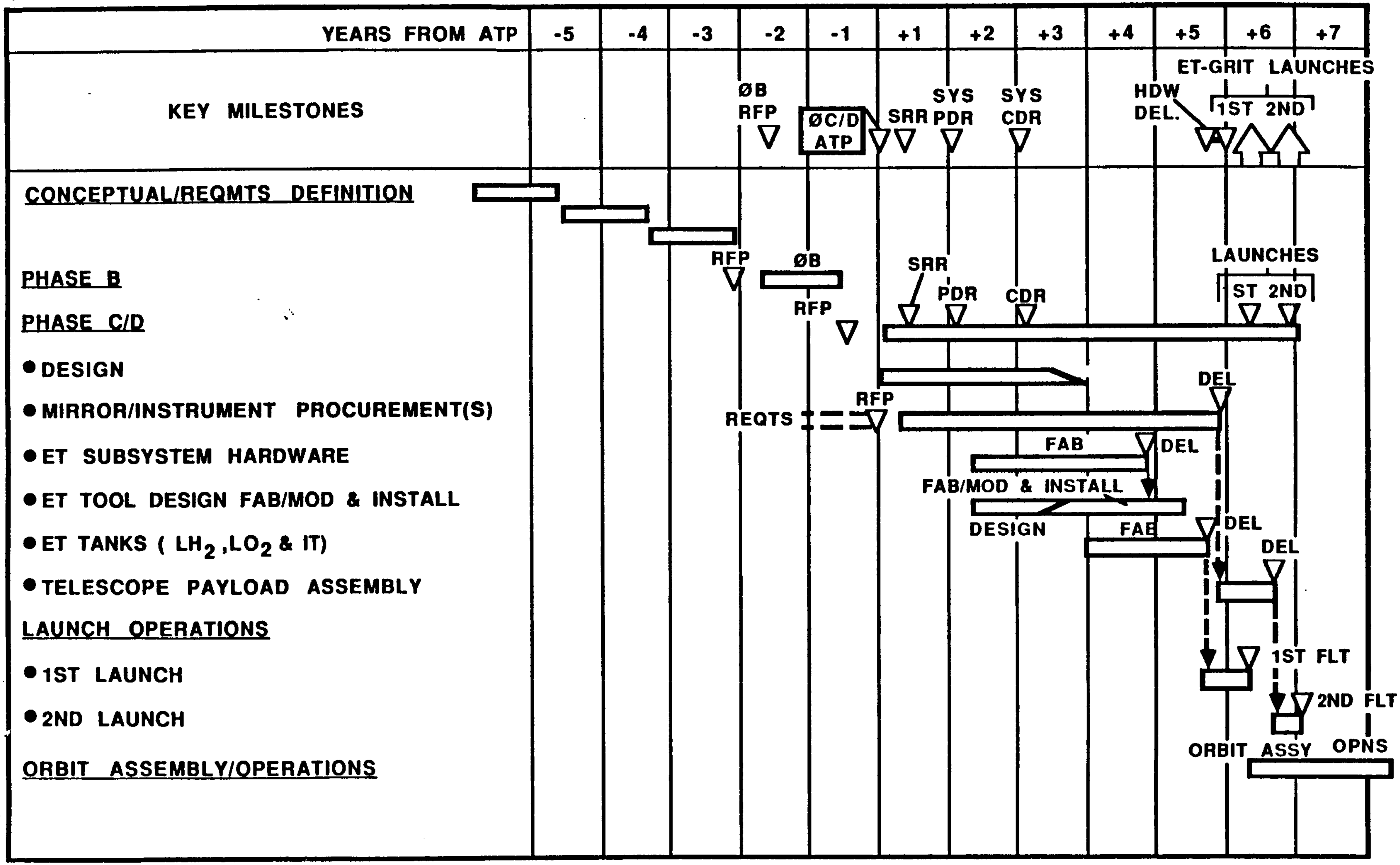
Defined Programmatic Issues

- ET Modifications
  - LO2 Tank
  - Intertank - Additions
  - LH2 Tank

- Tooling Requiremnents
  - New
    - -- Counterbalance Beam (Positioning)
    - -- Transfer Plates (Aligning)
    - -- Horizontal Intertank Access Scaffold
    - -- Cell "E" Cleaning Probe
  - Modifications
    - -- Intertank Vertical Access Kit
    - -- Proof Load on Intertank Lift Adapter
  - Test and Checkout Equipment (All Systems)

EXTERNAL TANK-GAMMA RAY IMAGING TELESCOPE (ET-GRIT)

1-637-8-2D



ET-GRIT Cost Ground Rules & Assumptions

- DDT&E
  - Soft Tooling Will be Used
  - Test Hardware
    - Majority of Test Hardware Will be Used in Flight Article
- Operations
  - Shuttle
    - Three STS Flights are Required
    - Costs Based on STAS Cost per Flight
    - Costs Shared by Non-GRIT Payloads
  - EVA
  - OMV Will Make 2 Visits to GRIT
    - Initial Dock
    - Deorbit
  - Mission Control
    - Monitor "On Station" GRIT for 5 Years
    - Use Existing Facilities
    - Utilize TDRSS Communications Link

GRIT No. 1 Power Bay Enclosure ROM Estimate

- Costs In 1987 Dollars And Exclude Fee and Contingency
- Estimate Only Includes Power Bay Enclosure No. 1 Impact To Hardware, Costs As Worst Case
  - Other GRIT Enclosures Not Considered
- Estimate Includes One Time Assembly And Checkout

Hardware Impacted	Element of Work	ROM Estimate	
		Nonrecurring	Recurring
ET Intertank	Strengthening Panel 7 Intercostal Attach Hardware Reinforcing Doublers	$ 1,025 K	$ 7 K
Power Bay #1 Contents	Power Distribution Boxes NiCad Batteries Charge/Current Controllers DC-DC Converters	$ 910 K	$ 435 K
Power Bay Packaging	Enclosure Box Support/Attach Brackets Thermal Protection Blanket (MLI)	$ 550 K	$ 140 K
Total ROM Cost		$ 2,485 K	$582 K

MARTIN MARIETTA
MANNED SPACE SYSTEMS

Life Cycle Costs (1987 $M)

Phase		Cost Element	
DDT&E	$102	Program Support	5
		Engineering	34
		Manufacturing	59
		Test	4
Operations	$ 98	Program Support	2
		Shuttle	58
		EVA	13
		OMV	6
		Mission Control	19
Total	$200		

Escalation Factor 1.056 86-87$

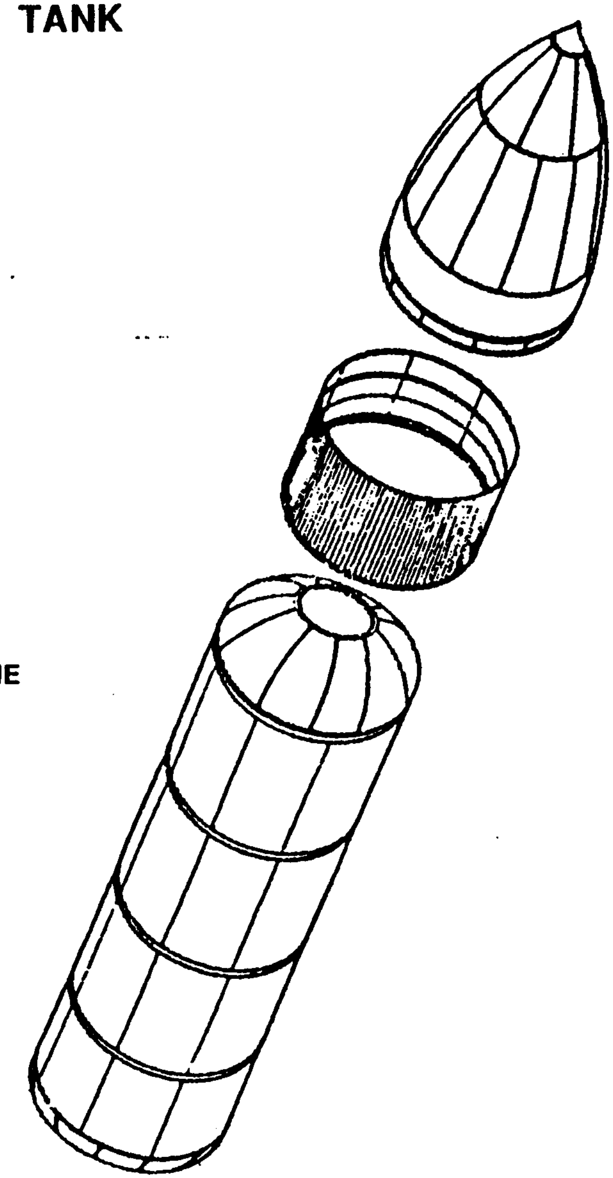
Summary

Potential Scientific Uses of External Tanks

- Symposium and Workshop on Scientific Use of Orbiting Shuttle External Tanks, Boulder, Colorado, August 3-4, 1987
  - Sponsors
    - University Corporation for Atmospheric Research (UCAR)
    - University of Colorado Center for Space and Geosciences Policy
    - National Aeronautics and Space Administration
    - Martin Marietta Corporation
    - University Space Research Association
  - Identified Areas of Concern for Research and Applications in Space
    - Engineering
    - Logistical
    - Organizational
  - Identified Scientific Applications
    - Astronomy and Astrophysics
    - Life Sciences
    - Material Sciences
    - Earth Observations

MARTIN MARIETTA
MANNED SPACE SYSTEMS

POTENTIAL USES OF THE EXTERNAL TANK



- TIN CAN USE
  - STORAGE FACILITIES
    - --LIQUIDS/GASES
    - --TOOLS AND EQUIPMENT
    - --WASTE/DISPOSAL
  - HANGAR
  - PRESSURE VESSEL FOR SCIENTIFIC DISCIPLINES (I.e. GRIT)
- OMV DOCKING AND OPERATIONS TRAINING FACILITY
- ROBOTICS LAB
- PROPELLANT RESOURCE
  - SCAVENGING OF RESIDUAL PROPELLANTS
  - POWDERING OF ALUMINUM AS REACTION MASS IN A1-02-H2 ENGINE
- STRUCTURES
  - PARTIAL DISASSEMBLY AND RE-ASSEMBLY INTO OTHER RIGID STRUCTURES
  - CUT INTO STRUCTURAL COMPONENTS
  - TESTBED OR STRONGBACK FOR CONSTRUCTION OF OTHER STRUCTURES
- TETHERS
  - GRAVITY GRADIENT "ANCHOR"
  - MOMENTUM EXCHANGE DEVICE FOR SHUTTLE DEORBIT
  - ELECTRICAL POWER GENERATOR
- MISCELLANEOUS
  - EARTH AND ATMOSPHERIC OBSERVATIONS PLATFORM
  - BIOLOGICAL AND LIFE SCIENCE FACILITY
  - PASSIVE LIFE SUPPORT SYSTEM (LIFE BOAT)

Conclusions and Recommendations

- Onorbit Conversion of ET to Gamma Ray Telescope/Spacecraft is Feasible
  - Technology Requirements
  - Mission Time Lines
  - Payload Capability/Delta Payload Opportunities
- Development Time and Cost are Acceptable
  - Five Years for ET Mods/Science Instruments
  - 200 M Dollar Development and Operations for 5 Years
- Specific Engineering R&D Required (Ground Based Testing)
  - Meteoroid Protection/Damage Repair
  - Thermal Gradients Control
- Conduct Phase III Analyses and Tests
  - Further Verification of Solutions to Specific Technical Areas
- Develop Pathfinder Mission as Precursor to ET Utilization
  - Orbit/Deorbit
  - OMV Docking/Training
  - Astronaut EVA/ET Entry
  - Tethered Artificial Gravity
- Develop Concepts for Onorbit Utilization of ETs
  - Robotics Training Facility
  - Tool/Equipment Storage
  - Maintenance Hangar

TASKS FOR PHASE III

- METEOROID/THERMAL CONTROL SHIELD CONCEPTUAL DESIGN
- THERMAL CONTROL ANALYSIS AND MATH MODELING
- INSTALLATION OPERATIONS
  - TRANSPORTATION AND INSTALLATION OF SHIELD
  - TIME LINES AND EVA TOOLS
- MIRROR AND INSTRUMENT INSTALLATION
- GROUND TEST SIMULATIONS
  - THERMAL CONTROL SYSTEM TEST BED
  - LIGHTING AND COMMUNICATIONS
  - METEOROID SHIELD MATERIALS EVALUATION (L.G.G.)
- ET GRIT APPLICATIONS USING SHUTTLE C